Corrosion

IN THIS ISSUE:

New Features: This Month in Corrosion Control; Long Term Advantages of Corrosion Control—An Editorial

This Month in Corrosion Control . . .

WHEN YOU ARE THERE IN PERSON you can ask and get answers to your questions on corrosion control. This is a principal reason for technical personnel to attend meetings such as the March NACE Conference in Dallas. By circulating among the hundreds of corrosion experts there, listening in on technical committee meetings, asking questions following presentation of technical papers or attendance at one of the two round table sessions the visitor gets a chance to have his questions answered.

SOMETHING FOR ALMOST EVERYBODY . . . As nearly as such a thing is possible the NACE national meeting offers programs of interest to almost everybody. More often than not a principal complaint concerns why so many interesting things are going on at the same time. See Advance Program, 16th Conference and 1960 Corrosion Show, Page 31.

HOW TO TELL IN ADVANCE whether or not the alloy in aircraft wing stiffeners is susceptible to stress corrosion is important because of the normally low safety factor used in aircraft wing designs, compared to such structures as railroad bridges, for example. A discussion of progress in this important field begins on Page 125.

VALUE OF SANDBLASTING in lengthening the life of protective coatings exposed in severely corrosive environments is among the subjects discussed in an article beginning on Page 93. The article also shows there's a difference in the effect of the elements in New Jersey and Texas seacoast environments.

HOW TO CONDUCT A COATING PROGRAM is spelled out in detail in an article beginning on Page 13. Importance of good records, painter education, sensible specifications and safety precautions are covered in this four-part article the first two parts of which are in this issue. More information in this same area is in an article beginning on Page 89 where a method of screening paints to select a specific material to match exposures is covered. How a punch card can be used to advantage is described.

ALLOY SELECTION FOR REFINING and petrochemical plants requires careful consideration of all the corrosion factors involved. How one large and progressive company conducts its operations in this

area and how it maintains a continuous watch on performance is explained in an article beginning on Page 107.

EVEN A VERY SMALL QUANTITY OF WELDING SLAG can lead to serious consequences in a hydrogen reforming furnace operating at 1500-1800 F. What to do about preventing corrosion from this source is described in an article beginning on Page 114.

EPOXY RESINS' use as materials of construction are considered in a down-to-earth article beginning on Page 9. Some good tips are given on how these important resins can be used to advantage.

CHEMICALS ARE BEING USED with greater frequency for cleaning refinery and petrochemical equipment. Because there are very few contract cleaners in Europe, cleaning must be done by the companies themselves. How the Royal Dutch-Shell Group goes about it and the equipment used is described in an article beginning on Page 97.

HOW TO KEEP ACIDS FROM EATING UP FLOORS is the subject of a technical report by NACE's committee 6-K on Corrosion Resistant Construction With Masonry and Allied Materials. Information given is approved by the committee, which is made up of the men with long experience with the materials discussed. The report begins on Page 117.

WHAT KIND OF SURFACE YOU START WITH is an important factor in estimating the cost of sandblasting operations. Some of the pitfalls in relying wholly on specifications based solely on application and time are described in a color slide illustrated commentary available from NACE. The slide talk, based on a recent paper at NACE's committee on surface preparation is free on a loan basis to anyone interested. It is described more fully on Page 25.

WHICH WAY CORROSIVE FUMES BLOW is checked with high accuracy by a weather team in Georgia. Interesting details on how they do it are given on Page 59.

20 CARLOADS A DAY of line pipe can be cleaned and coated inside and out in a new Houston Ship-channel plant. Photographs and story on this highly mechanized operation are given on Page 64.

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Use of Polyester and Epoxy Resins for Chemical Plant Repairs, by Walter A. Szymanski

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Use of High Silicon Cast Iron for Anodes. Fourth Interim Report of Unit Committee T-2B on Anodes for Impressed Current.

The Oxidation of Metals by Carbon Dioxide at Temperatures of 1100 F to 1740 F and Pressures of 1000 to 2000 psi, by J. C. Bokros and W. P. Wallace.

Corrosion Behavior of High Purity Vanadium, by David Schlain, Charles B. Kenahan and Walter L. Acherman.

Corrosion Testing of Two Zirconium Alloys, by Stanley Kass.

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The Effect of Velocity on Corrosion, by H. R. Copson.

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Non-Metallic Pipe for Liquid Corrosives, by C. A. Burt.

Application of Anodic Corrosion Control in the Chemical Industry, by D. A. Shock, O. L. Riggs and J. D. Sudbury.

Anodic Passivation Studies, by J. D. Sudbury, O. L. Riggs and D. A. Shock.

Anodic Control of Corrosion in a Sulfonation Plant, by O. L. Riggs, Merle Hutchison and N. L. Conger.

— AN EDITORIAL —

Long Term Advantages of Corrosion Control

WHILE optimistic on the whole about avoiding ultimate exhaustion of the world's mineral resources, a British writer* discussing this subject gives the following table on the approximate time when world reserves of some metals will be exhausted:

Mineral	Years of Supply
Iron Ore	825
Manganese	250
Tungsten	125
Copper	45
Lead	33
Zinc	39
Tin	38

These times are based on consumption at present rates. While it is a fallacy to assume that the rate of consumption of metals will not continue to increase in the future as it has in the past, this estimate, even if only approximately correct, indicates immediate attention should be given to the non-ferrous metals with the shortest supply outlook. Less urgently, it also indicates that more attention should be paid to ferrous resources.

The remedy that offers the most positive hope of immediate improvement is the recycling of metals fabricated but no longer in use. A corrolary of this remedy is the need to protect them against corrosion so that they will be available for recycling.

Another remedy that suggests itself is a change in the manner of using the metals in shortest supply. This includes concentrat-

ing their application to alloying and limiting their use in the pure state to those installations where it is unavoidable.

Another helpful change would be increasing their use as cladding or plating.

On a like premise that energy also must be conserved, the same author cites the difference in energy required to produce aluminum as 20 times that required to produce steel. If energy is to come largely from mineral hydrocarbons in the future as it has in the past and does now, there is good reason to use it to best advantage. The argument for energy conservation applies equally well if it be assumed that nuclear sources eventually will supply the bulk of civilization's energy needs, because the ores from which atomic fuels are derived also are exhaustible.

In summary then, it becomes increasingly important that metals be protected against corrosion—in the process of which they become so dispersed they cannot be recovered economically—as the time approaches when some of the commonly used metals near exhaustion. This consideration is in addition to that of immediate economic necessity which motivates corrosion-control schemes today.

Of course, if man succeeds in making a mine of the moon or can exploit some as yet undreamed of principle of energy production, these contentions may no longer be valid.

* Alex Keynes. "Economic Aspects of Corrosion," a lecture given to the Corrosion Group of the Society of Chemical Industry, London, March 18, 1959.

TECHNICAL TOPICS

Precision Parts Are Cast From Epoxy Resin Systems*

Abstract
Briefly discusses physical properties and chemical resistance of basic epoxy systems. Also includes modified epoxy systems and laminated epoxy systems. Gives manufacture procedures for casting precision parts and lists some applications.
6.6.8

Introduction

EPOXY COATINGS, due to their inherent chemical structure, exhibit outstanding chemical resistance, flexibility, and adhesion—those characteristics demanded of acceptable protective media.

Epoxies also exhibit useful mechanical and physical properties. Epoxy parts, for example, offer high tensile and flexural strengths, good impact strengths and other mechanical and chemical properties. Glass cloth and epoxy resins offer a rapid and efficient method of reducing maintenance costs of chemical equipment. Hence, epoxy resins have become well known as engineering materials for applications where chemical resistance and high mechanical strengths are required.

Basic Epoxy Systems

Basic epoxy systems consist of a resin which can be anything from a low viscosity liquid to a high melting point solid and a hardener or cross-linking agent.

★ Revision of a paper entitled "Epoxy Resin Structures in Corrosion Resistant Applications" by Elliott N. Dorman and William Ibsen, Ciba Products Corp., Fair Lawn, N. J., presented at the 15th Annual Conference, National Association of Corrosion Engineers, March 16-20, 1959, Chicago, Ill.

The hardener can be of the amine or acid-anhydride type. Hardening can take place at room or elevated temperatures, depending upon the cross-linking agent used.

Physical Properties

The properties given in Table 1 are for four unfilled systems containing only epoxy resin and hardener. The data show the range of physical properties and handling characteristics of typical systems in use.

Chemical Resistance

As in the case with mechanical properties, the chemical resistance properties of epoxies also are dependent upon the particular system under consideration. Chemical resistance data are given in Table 2 for two systems covered in Table 1.

Different systems do not have the same resistance to various chemical reagents. Anhydride cured hot melt systems are frequently preferred for long term resistance to many chemicals. Where handling requires the use of a liquid system, aromatic amines such as m-phenylene diamine and methylene dianiline are preferred for acid and caustic resistance. Many variations in the cure of these basic systems are possible which alter the properties listed. Generally, increases in the cure temperature increase the flexural deformation temperature and ultimate resistance to heat aging. Slower cures at more moderate temperatures result in systems that have lower shrinkage during cure and higher impact resistance.
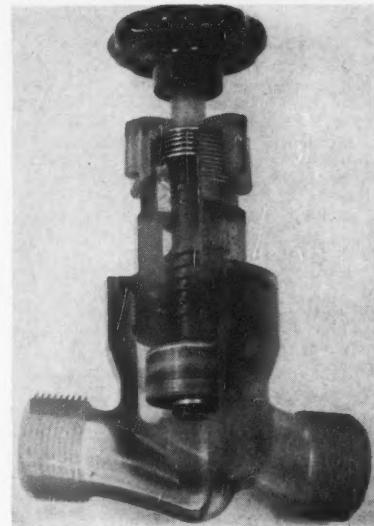
Figure 1—Cast valve molded from a solid resin/anhydride system.

Properties for basic systems can be summarized as follows:

1. Cures are obtainable from room temperature to 200 C.
2. Systems having flexural deformation temperature from less than 60 C to more than 150 C are available.
3. Both liquid and solid resins and hardeners can be used.

Modified Epoxy Systems

These basic systems usually are formulated or compounded to produce materials specifically designed for a given end-use. Inert inorganic fillers are frequently added to reduce cost, lower shrinkage, alter certain physical properties and to lower coefficient of thermal expansion.

Other modifiers such as plasticizers and flexibilizers, reactive diluents, coloring dyes or pigments and inexpensive

TABLE 1—Properties of Four Unfilled Epoxy Resin Systems

	502	6005	6005	6060
Epoxy Resin[1]	502	6005	6005	6060
Hardener	Triethylene tetramine	m-Phenylene Diamine	Methyl nadic anhydride	Phthalic anhydride
Characteristics of Uncured System:				
State	liquid	liquid	liquid	hot melt
Hardener Type	liquid aliphatic amine	solid aromatic amine	liquid anhydride	solid anhydride
Suggested Curing Conditions	24 hr at 40C or 2 hr at 100C	2 hr at 85C + 4 hr at 150C	2 hr at 100C + 2 hr at 150C + 2 hr at 200C	14 hr at 130C or 4 hr at 150C
Physical Properties of Cured System at 23C				
Ultimate Tensile Strength, psi	9,000	13,000	12,000	12,000
Modulus of Elasticity, psi	0.45×10^6	0.44×10^6	0.76×10^6	0.45×10^6
Ultimate Flexural Strength, psi	15,000	18,000	20,000	19,000
Modulus of Elasticity, psi	0.40×10^6	0.46×10^6	0.43×10^6	0.40×10^6
Flexural Deformation Temp, C	60	150	150	109

[1] Ciba epoxy resin numbers.

Precision Parts –

(Continued From Page 9)

liquid extenders also can be added to the basic systems.

The desired end properties usually can be obtained by proper compounding of resin, hardener, filler and selected modifiers.

Laminated Epoxy Systems

A wide range of properties also is available in laminated epoxy systems. Many reinforcing media are available including the well known glass fibers (in the form of fabric, woven roving, mat, etc.), synthetic fabrics, asbestos and the newer materials such as woven fused quartz, glass flake, etc.

Table 3 illustrates the range of outstanding physical properties offered by glass reinforced epoxy laminates. The first two resin/hardener systems are suitable for wet lay-up techniques. The third is best suited for dry lay-up use.

Table 4 shows the chemical resistance of two of the epoxy/glass laminated systems given in Table 3.

Manufacturing Procedures

Epoxy resins cure or harden by addition polymerization without the evolution of water or other volatile materials. This desirable hardening reaction largely accounts for the low shrinkage during curing. The resulting casting therefore is relatively free of stresses and is mechanically sound.

This low, predictable and uniform shrinkage makes possible the manufacture of precision parts. Epoxies are used to great extent in automotive and aircraft tooling. Therefore, the accuracy and surface of the casting reflects the condition of the mold.

Another epoxy property is their outstanding adhesion to most surfaces. This characteristic, coupled with the low curing shrinkage, requires careful mold design and preparation.

The molds used for casting can be made of almost any material capable of withstanding the pouring and curing temperatures. Molds have been made from various metals (aluminum, steel and low melting alloys), plaster (properly dried and sealed), wood, fused vinyl plastisols, glass and plastics including cast epoxies. In all cases, mold release should be used, and slight drafts incorporated in the mold design. Parts having undercuts can be cast in flexible (vinyl) or split molds.

Thoroughly mixed resin and hardener are poured at the temperature required for the system. Molds are pre-heated to about 10 C higher than that of the casting material. Normal casting or foundry techniques are used: Pouring into an inclined mold; pouring to the lowest point; vented molds to permit easy air escape; etc.

The filled mold is allowed to cure at the prescribed temperature and time. Generally, the gelled part can be removed from the mold and permitted to continue its cure, thus releasing the mold for further production.

Automatic proportioning, mixing, evacuating and dispensing equipment is available for continuous casting into conveyorized molds. The use of low melting alloys and master arbors permits the continuous production and melting of molds.

Applications

A cast valve (shown in Figure 1) de-signed for 90 psi was molded from a solid resin/anhydride system. The threads were cut after the valve body was cast.

Other applications of the epoxies are pipe joints, friction cocks and free-flow valves. A 50-feet high and 40-inch diameter exhaust stack was made of an epoxy-glass cloth laminate to combat corrosive flue gases. The stack consisted of two concentric reinforced tubes with a separating layer of polyurethane foam. It was made in 40-inch sections and cemented together with an epoxy adhesive.

The technique used to make a cock is shown in Figure 2. The mold is opened to show end caps, top and bottom inserts for the core.

TABLE 2—Chemical Resistance of Two Epoxy Resin Systems

Epoxy Resin[1]	502	6060
Hardener	Triethylene tetramine	Phthalic anhydride
Immersion Time at 23°C	3 months	1 year
Percent Weight Change after Immersion Reagent		
Sulfuric Acid, 30 percent	....	+0.6
Sulfuric Acid, 50 Percent	+2.6	....
Hydrochloric Acid, 10 Percent	+2.2	+0.7
Nitric Acid, 10 Percent	+2.7	—0.8
Caustic Solution, 10 Percent	+1.1	+0.8
Ethyl Alcohol, 95 Percent	+9.0	+1.5
Butyl Alcohol, 100 Percent	+0.9	....
Hydrogen Peroxide, 30 Percent	+13.0	....
Hydrogen Peroxide, 3 Percent	....	+0.9
Ammonia, 10 Percent	+1.2	+0.9
Sodium Chloride, 10 Percent	+1.1	+0.7
Acetic Acid, 5 Percent	....	+0.9
Carbon Tetrachloride, 100 Percent	+7.9	....
Gasoline	+0.003	....
Triethanolamine	—0.01	....

[1] Ciba expoxy resin number.

TABLE 3—Physical Properties of Glass Reinforced Epoxy Laminates

Epoxy Resin[1]	502	6005	6020
Hardener	Triethylene tetramine	957[1]	HET Anhydride
Suggested Curing Conditions	2 hr at 100C	3 hr at 80C + 4 hr at 206C	2 hr at 150C
Physical Properties of Cured System at 23C			
Ultimate Tensile Strength, psi	54,000	57,000	65,000
Modulus of Elasticity, psi	3.4 x 10^{6}	3.5 x 10^{6}	3.4 x 10^{6}
Ultimate Compressive Strength, psi	33,000	60,000	40,000
Ultimate Flexural Strength, psi	68,000	83,000	78,000
Modulus of Elasticity, psi	3.0 x 10^{6}	3.7 x 10^{6}	3.3 x 10^{6}

Laminate Makeup—14 plies 181 glass cloth ¼-inch thick laminate.
[1] Ciba numbers.

TABLE 4—Chemical Resistance of Two Epoxy-Glass Laminated Systems

Chemical Reagent Solution	6005[1] Hardener 957[1]		6020[1] HET Anhydride	
	Percent Weight Change	Percent Flexural Strength Retained	Percent Weight Change	Percent Flexural Strength Retained
3 Percent Sulfuric Acid	+0.05	88	—0.2	86
10 Percent Sodium Chloride	+0.3	96	......	....
Distilled Water	+0.3	96	+0.3	91
10 Percent Nitric Acid	+0.1	84	—0.1	41
10 Percent Hydrochloric Acid	+0.1	86	—3.6	49
5 Percent Acetic Acid	+0.3	95	+0.2	100
3 Percent Hydrogen Peroxide	+0.3	94	+0.2	33
Petrohol 99	+0.1	98	+0.1	100
Hydrocarbon Test Fluid	+0.1	99	+0.1	98
Ethylene Glycol	+0.1	97	......	....
Hydraulic Oil	+0.1	98	......	....

Figure 2—Opened view of a mold used to cast a cock (lower right). End caps, top and bottom inserts are shown also.

Precision Parts —

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The base for a signal light to be used in presence of corrosive flue gases also has been cast of a highly filled epoxy system (Figure 3).

A 30-KV transformer, shown in Figure 4 has been fabricated with the primary windings completely encapsulated with a filled epoxy resin system. The same material was used for the transformer casing all cast in one operation.

DISCUSSIONS

Question by Fred O. Beckmann, American Cyanamid Co., New York, New York:

What is the effect of nuclear radiation upon the properties of epoxy resins and possible uses of these resins with this exposure?

Reply by William Ibsen:

We have not developed any data on
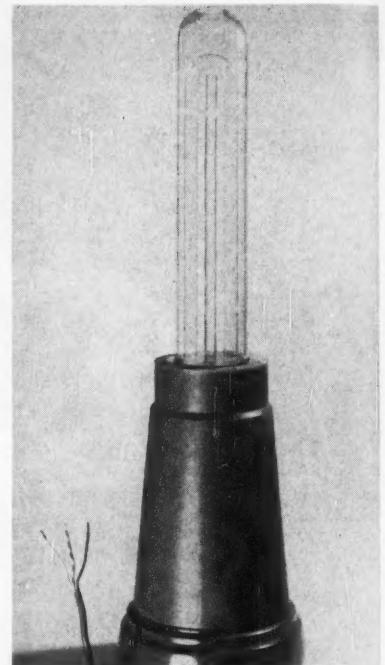
Figure 3—Base for a signal light to be used in presence of corrosive flue gases. Base was cast of a filled epoxy system.
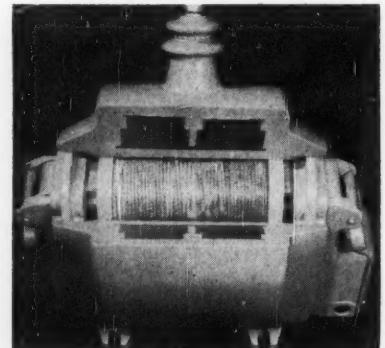
Figure 4—Primary windings of a 30-KV transformer were encapsulated with a filled epoxy resin system. Transformer casing also was made of the same materials.
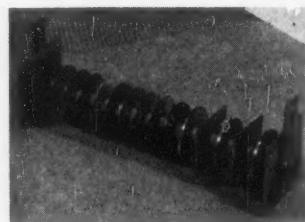
these effects ourselves, but recent articles in the literature cover this subject.

Question by Orest B. Draganuk, Canadian Chemical Co., Ltd., Edmonton, Alberta, Canada:

Is any data available on corrosion resistance of either epoxy or furane resins in boiling 1 percent H_2SO_4 with ozone added?

Reply by William Ibsen:

No, to our knowledge.

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Canadian Region's Eastern Division Conference will be held January 17-20 in Toronto.

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Houston Section's 5th annual corrosion control short course will be held January 28-29 at the Rice Hotel, Houston, Texas.

Engineering Approach to a

CHEMICAL PLANT COATING PROGRAM*

Part 1 – Records That Help Keep Track of Costs and Prove Results

Abstract

Specimens of records used to keep track of a painting program at a seacoast chemical plant are shown. How these records help the coating engineer keep track of his work and how they can be used to estimate costs are explained.   1.2.2

IN ORDER to effectively and economically direct an effective coating program, it is necessary to collect and summarize pertinent information in an orderly way.

The four forms shown in Figure 1 give a standing of the department program which can be reviewed quickly and from which up-to-date reports can be prepared.

The Preventive Maintenance Corrosion Control Program Master List is designed to show the basic summarized information needed to keep the program organized and under control.

Total square footage of structural steel, piping and vessels in the corrosion control program are measured by section according to physical layout or accounting practices. Brief plot plan sketches are made and numbered to show these locations. This information is filed by area.

Heading of the master list has spaces for posting the area number and description. The section number of the area is entered in the left hand column followed by the description and square footage of the particular section. By adding this column the area square footage or total square footage in the entire program can be determined.

Work order numbers are entered on this form as they are received. A folder is made for each order and placed in an open order file in numerical sequence. When the order is completed and closed the total cost charged to the job is entered in the proper year column. The order folder is then placed in the closed order file for reference purposes. The master list can be used to refer to open or closed work orders covering any section or area of the plant.

Total cost for any given section over a period of years or the monies spent on the program in any area or the entire plant are easily computed from this master list on all completed orders.

Each work order classified as preventive maintenance is entered on the Work Order Yearly List, when it is received. This information is necessary in order to keep a close check on the progress being made in the program.

Under date is shown time when order is received, work started, job completed and account closed.

Entries under location by area and description show where the work is being done and are helpful in referring to the master list.

Year column is needed because some jobs will not be completed at the end of a fiscal year. When the job is not complete, entries under dollar cost are made showing monies spent during the current year and a note is made under description "See Following Yearly List." Previous year entry is then duplicated on the new yearly list.

The dollar cost columns are a convenient way of showing labor, material and total job cost. The breakdown of the program cost into labor and material can be made from this list. The total cost is entered on the master list.

Cost per square foot calculations of the different operations involved in a corrosion control program are important in order to control monies expended. This information has been made easily available by the cost per square foot resume form.

Work order number, area, description and square foot columns are used as in the two preceding forms. The rest of the form is used to show cost of the different operations.

At a glance the cost of any operation or the average total cost for the complete job can be compared on different orders. Under "coats" additional columns may be added and the material trade names written in so comparative cost on different systems can be checked.

Painting Department Manpower Assignments form is used to show how every man's time is spent during the month by days.

The working days of the month are written in under "date."

Under preventive maintenance all the work orders and job locations which are worked on in the current month will be listed. The preventive maintenance daily total line will give the man days spent on this work.

Work orders other than preventive maintenance listing include new construction, repair to surface damage by the operating or maintenance people and any other work which cannot be classified as preventive maintenance corrosion control work.

Place for inspector's time is included. One or more men from the maintenance painting group are used as inspectors when contractors are doing work on the corrosion control program.

Men used in the sandblast yard, doing sign writing or absent from work for any reason are shown. The daily grand total accounts for all men in the department.

This form can be used to review manpower usage by the day, month or the entire year can be summarized from this information.

Corrosion Control Program Cost Analyzed

Industrial plant management is sometimes faced with added corrosion control cost due to construction expedients caused by the time element or other factors. In recent years there has been an increasing awareness of savings to be had through a carefully planned corrosion resistant coating program for all structural steel, piping and vessels. So, in planning new construction a decision must be made between a corrosion resistant coating system of low initial cost and one based on a low cost per square foot per year. The two programs can be very similar in specifications and material used. Difference in cost can result from surface preparation, film thickness, field welds not properly cleaned, extensive use of brackets and supports which are not prepared for coatings, etc.

Table 1 shows an analysis of the comparative cost of these two approaches on percentage basis when the original optimum program cost is called 100 percent. While actual job cost may be more or less, the percentage between the two systems is assumed to be constant.

TABLE 1—Corrosion Resistant Coating Programs Cost Comparison*

Period Covered	Optimum Cost Program		Low Initial Cost Program	
	Percent Cost	Sq. Ft. Cost In Cents	Percent Cost	Sq. Ft. Cost In Cents
Original	100	50	60	30
First Year Follow-up	17.50	8.75	120	60
Two Year Total	117.50	58.75	180	90
Third Year Touch-up	8.50	4.25	8.50	4.25
Seven Years at 8.50 Percent Each Year	59.50	29.75	59.50	29.75
Ten Year Total	185.50	92.75	248	124

* All comparison costs are based on the Original Optimum Program Cost being 100 percent. Fifty cents per square foot used arbitrarily as Original Optimum Program Cost.

Engineering Approach —

(Continued From Page 13)

Under the optimum program the cost for the first two years would amount to 117½ percent and under the low initial cost program it would amount to 180 percent. The cost for the next several years for the two different approaches would be the same, or 8½ percent per year. These values are based on getting the protective coating system in a first class condition and keeping it that way.

The optimum program would be cheaper for the first two years by 62½ percent and the advantage would continue over a period of years.

The high cost for the second year of the low initial expenditure program is explained by the need for extensive surface preparation under difficult plant operating conditions and the volume of coating materials used over large areas.

Fifty cents per square foot has been used arbitrarily to represent 100 percent cost in order to show in a more tangible way the relative cost of the two different approaches to the same problem.

Thirty cents a square foot savings can be realized in the first few years by following the optimum program. This represents a sizeable sum of money when several hundred thousand square feet of surface to be protected are involved.

Figure 2 illustrates the comparative cost information in a graphic form.

The advisability of using a low original cost program, and periodically recoating every several years must be weighed against the corrosion rate which could make it necessary to replace structural steel, piping or vessels.

The preceding discussion on corrosion control program cost has lumped all exterior surfaces together giving average cost which might be expected. Touch up work may be carried out on major areas at less than 25 percent of the average cost and water tanks hot lines, etc., will cost considerably more than average.
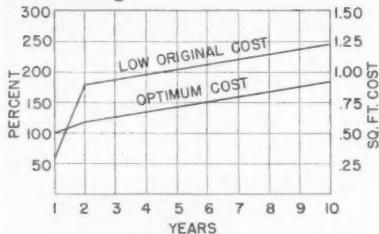
Figure 2—Coating programs cost comparison.

Figure 1—Four forms designed for simplified corrosion control program records.

Part 2—Training Men to Make the Program Work

Abstract

The philosophy and some of the subjects covered in a painter education program at a chemical plant are described.   1.7.3

A SUCCESSFUL corrosion control program is dependent on the quality of the men hired and the way they are trained to carry out their work. Because the men should be selected with the idea of long time employment in mind, the first level supervisor makes the final choice because he is responsible for the employee's performance.

Training actually starts during the pre-employment interview period. Company policies are explained and the man is told in considerable detail how he will fit in the organization and what is expected of him in the painting department before he is placed on the payroll.

The corrosion control training program at Union Carbide Corporation's Seadrift, Texas plant is based on the fact that a person learns rapidly by actually doing the work. In order to further expedite trainee development two hours each week is set aside for classroom study, discussion, instruction by the immediate supervisor or other qualified people.

Classroom work covers several methods of surface preparation: 100 percent sandblasting for new work, spot or brush blasting and hand chipping or brushing for preventive maintenance work; soap and water surface cleaning; solvent cleaning which reactivates old coatings for better adhesion of newly sprayed materials.

Reasons for the selection, composition and application of the various cor-

Rust Preventive Properties

of

Nonylphenoxyacetic Acid

in

Some Petroleum Products*

Abstract

Discusses laboratory tests which indicate nonylphenoxyacetic acid to be an effective corrosion inhibitor for ferrous metals in variety of petroleum based fluids. Also discusses inhibition in synthetic lubricants such as silicones. Presents data obtained and outlines test methods used. 2.3.4

NONYLPHENOXYACETIC ACID (Figure 1), a substituted phenyl ether carboxylic acid, provides efficient corrosion inhibition for ferrous surfaces in contact with both organic fluids and a corrosive aqueous phase.

Nonylphenoxyacetic acid is prepared by the reaction (Figure 2) of sodium chloroacetate with nonyl phenol in alkaline medium. Typical properties of nonylphenoxyacetic acid are presented in Table 1.

While protecting ferrous metal surfaces from corrosion by adsorbing on them to provide a closely packed protective film, nonylphenoxyacetic acid is convenient to use for these reasons: (1) It is readily soluble in petroleum and synthetic fluids and other organic systems over a wide temperature range. (2) It is insoluble in water, minimizing the tendency for the protective film to be desorbed by being leached into the aqueous phase. (3) Its rust preventive properties persist in the presence of other additives such as emulsifying agents, antioxidants, etc., and it appears to be compatible with these agents. (4) As a liquid, nonylphenoxyacetic acid can be adapted readily to a variety of blending techniques. (5) It is substantially all organic in nature, leaving little or no ash on combustion.

The structural features of nonylphenoxyacetic acid combine to present an efficient corrosion inhibitor of marked stability to chemical attack such as hydrolysis by acid or alkali, oxidation, etc. Nonylphenoxyacetic acid has exhibited no tendency toward metal dissolution over a wide range of use concentrations. Such metal dissolution frequently is the cause of surface staining and depletion of the inhibitor below effective concentrations.

Fatty acids, the more basic amines and other compounds capable of ionizing at an oil-water interface are more strongly adsorbed than other organic molecules such as alcohols, esters, ketones, amides, etc.[1, 2, 8] These classes of compounds are the most effective types of polar organic rust preventives.[4, 5]

The protective adsorbed film (or
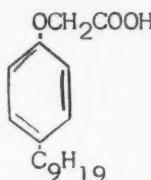
Figure 1—Molecular structure of nonylphenoxyacetic acid.

blanket) may inhibit the electrochemical mechanism of corrosion not only by physically preventing contact of the metal by corrosive agents such as acids, oxygen and other corrosive gases but also by increasing the true ohmic resistance of the conduction path and interfering with the anodic and cathodic processes by preferential adsorption at both anodic and cathodic areas.[6] It is also suggested that the effectiveness as corrosion inhibitors of polar organic compounds containing elements of group Vb of the periodic table (nitrogen, phosphorous) and group VIb (oxygen, sulfur, etc.) is due to their ability to donate electrons to the metal surfaces. The chemisorption component of inhibition is thus described as a coordinate chemical bond.

The increased effectivenes of nonylphenoxyacetic acid as a rust inhibitor compared to carboxylic acids of the fatty acid type may be related to the influence of the ether oxygen. For example, the neighboring ether oxygen may assist in augmenting rust preventive action by one or more of the following mechanisms: (a) by increasing

the ionization of the carboxyl group, making it more available for metal bond formation, (b) by providing an additional link to the metal surface by forming a coordinate bond between the ether oxygen with a neighboring metal atom and (c) in helping to form a relatively stable five-membered chelate ring of the type shown in Figure 3, where M is a metal atom still part of the crystal lattice of the metal surface.

Nonylphenoxyacetic Acid in Petroleum Fuels

Usefulness of product soluble inhibitors in preventing corrosion in pipelines and marine tankers carrying refined petroleum products such as gasoline, jet fuel and kerosene has been demonstrated.[7, 8]

Tests for evaluating the utility of inhibitors for this purpose generally simulate field conditions in the laboratory. The gasoline used in tests reported here was a straight run marine gasoline. Nonylphenoxyacetic acid is soluble in gasoline in all proportions at room temperature.

Test results were obtained with a commercial grade of nonylphenoxyacetic acid which contains about 70 per cent nonylphenoxyacetic acid. The other constituents of the commercial material are inert and organic in nature and do not detract from its performance characteristics.

TABLE 1—Typical Properties of Commercial Nonylphenoxyacetic Acid*

Flow point	0° C
Viscosity at 25 C	6500 cps.
Color (Gardner)	5
Residue upon ignition	0.1%
Sp. gravity at 25 C	1.01
Formula molecular weight	278
Solubility at room temperature	
in paraffinic mineral oil	infinite
in kerosene	infinite
in Stoddard solvent	infinite
in benzene	infinite
in water	insoluble

* Contains 70% nonylphenoxyacetic acid.
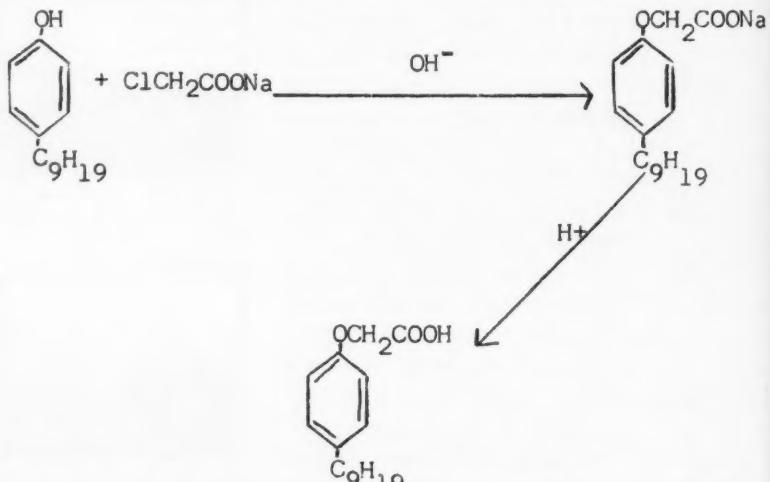
Figure 2—Chemical reaction of sodium chloroacetate with nonyl phenol in alkaline medium by which nonylphenoxyacetic acid is prepared.

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Rust Preventive—

Dynamic Immersion Test

The dynamic immersion test (Method A.S.T.M. D665-54[9]) was modified to run at 80 F for three hours with synthetic sea water and was designed to evaluate the rust preventive properties of inhibited gasoline when the aqueous and hydrocarbon phases are well stirred and are in contact with the entire immersed portion of the SAE 1020 steel test cylinder. The same test also was run on inhibited gasoline which had been subjected to a water extraction with 10 per cent by volume of distilled water.

Test results (Table 2) demonstrate the superior rust preventive effectiveness of nonylphenoxyacetic acid to another commercially available inhibitor under dynamic conditions before and after water extraction.

Static Immersion Test

The static immersion test[10] which is run under essentially quiescent conditions simulates those conditions found in storage tanks and in marine tankers during the cargo run.

A 6½ by 1 by 1/32-inch SAE 1010 cold-rolled steel strip cleaned and finished with 5/0 sandpaper is partially immersed in 100 ml of ASTM D665 synthetic sea water and 750 ml of gasoline contained in a one-quart jar. The system is thoroughly shaken for one minute and then set aside in the dark for three weeks at room temperature. The specimen is then removed, examined and rated by the system described in Table 2.

Table 3 indicates the unusual effectiveness of nonylphenoxyacetic acid in preventing corrosion of the steel exposed to the various phases.

Reverse Cycling Test

The reverse cycling test was devised to simulate conditions in a marine tanker through one complete cycle in which the bulkheads are filled first with re-

TABLE 2—Inhibitors in Gasoline*

	Original	After Extraction
Nonylphenoxyacetic acid 0.0050%............	1	2
0.0025%............	2	.
Compound C 0.0050%............	2	5
None.................	7	.

1—no rust.
2—trace of rust, few spots.
3—less than 5% of surface rusted.
4—5-50% of surface rusted.
5—50-99% of surface rusted.
6—Surface covered by light rust.
7—Surface covered by heavy rust.
* ASTM D665 Turbine Oil Rusting Test, Sea Water Method B.

TABLE 3—Inhibitors in Gasoline, Static Corrosion Test

Inhibitor & Concentration	Sea Water	Gasoline	Vapor Phase
Nonylphenoxyacetic acid 0.0050%..........	1	1	1
0.0025%..........	1	3	3
Compound C* 0.0100%..........	7	4	1
None	7	6	6

Ratings as Table 2.
* Compound C is a high molecular weight organic acid type rust inhibitor.
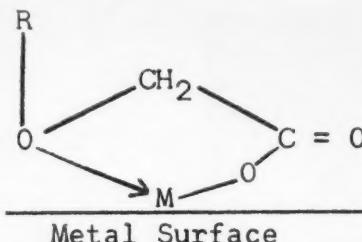
Figure 3—Chemical reaction of a five-membered chelate ring.

fined cargo, then are either ballasted with sea water or are maintained empty for the return trip. Tests similar in principle, if not in detail, have been used by others.[11]

Tarred, sandblasted specimens of SAE 1010 cold-rolled steel, 1 by 3 by 1/32-inch in size, are rusted by immersion in synthetic sea water for four days. They are air dried for one day, re-immersed in synthetic sea water for one day and finally air dried for one day more. This produces an adherent relatively uniform rust coating. The specimens are wetted in synthetic sea water and totally immersed in the test gasoline for one week at room temperature. They are removed and totally immersed in synthetic sea water for one week more. After this period at room temperature, the specimens are removed, brushed well and cleaned in inhibited acid. They are re-weighed and percent protection calculated.

Test results are recorded in Table 4. The superior corrosion inhibition of nonylphenoxyacetic acid compared to another commercial inhibitor is shown.

Solubility of Lead Salt of Nonylphenoxyacetic Acid

The lead salt of nonylphenoxyacetic acid prepared by double decomposition from the sodium salt and lead acetate shows good solubility in gasoline. Concentrations in the range tested (to 0.5 percent) were easily soluble at room temperature, indicating that the inhibitor will not precipitate in the presence of tetraethyl lead in gasoline.

Interaction of Water and Aviation Fuels

Federal Test Method Standard 791, Method 3251.7, indicates the tendency of the additive to cause emulsification or solubility of buffered water in aviation fuel. In the test, inhibited JP4 jet fuel was shaken vigorously with a pH7 phosphate buffer at room temperature for two minutes. The system was allowed to stand for five minutes at which time any volume changes and the appearance of the jet fuel water interface were noted. Nonylphenoxyacetic acid at 0.01 percent allowed complete separation of the two phases with a clean interface.

Copper Strip Corrosion by Petroleum Products

In a copper strip corrosion test at a concentration of 0.005 percent in marine gasoline, nonylphenoxyacetic acid did not cause any more tarnish than the base gasoline. Method ASTM D-130-56 was used for the test.

Nonylphenoxyacetic Acid in Lubricants, Hydraulic Circulating, Instrument and Preservative Oils

Product soluble inhibitors combining

rust preventive properties with chemical and thermal stability are required for the lubrication and protection of the closely engineered mechanisms in steam and gas turbines, engines and aircraft instruments.

Test methods for evaluating rust preventing efficiency of nonylphenoxyacetic acid in petroleum and synthetic liquids designed for such systems were the following: (1) Static water drop test (Federal Test Method Std. 791, Method 5311), (2) Turbine oil rusting test (ASTM D665-54 Proc. B) and (3) Humidity cabinet test (JAN-H-792).[12] These test methods are listed in relative order of severity.

Static Water Drop Test

The mineral oil used in the static water drop test and the following tests, unless otherwise noted, was a non-additive, solvent-extracted turbine grade lubricating oil of 183 SUS at 100 F. Nonylphenoxyacetic acid is miscible with this oil in all proportions at room temperature. This test involved observing rust formation at 140 F on a 1.75 inches triangular cold-rolled steel specimen immersed in oil when a 0.2 milliliter drop of distilled water was inserted in the centrally located dimple of the test-piece.

Inhibitor efficiency in this test was indicated by the minimum inhibitor concentration required to prevent corrosion for two weeks under test conditions. The calcium and barium salts of the acid also were effective inhibitors in this system.

Nonylphenoxyacetic acid also was tested in a silicone fluid. In this system the inhibitor was less effective than in petroleum oil although its rust inhibiting properties were still pronounced. Data are recorded in Table 5.

Turbine Oil Rust Test

The turbine oil rust test method involved stirring a mixture of 300 ml of oil under test with 30 ml of synthetic sea water at a temperature of 140 F with a cylindrical steel specimen completely immersed. Results (Table 6) in-

TABLE 4—Inhibitors in Gasoline, Reverse Cycling Test

Inhibitor and Concentration	Ratings Percent Protection	ipy	mdd
Nonylphenoxyacetic acid			
0.0025%..........	25.7	0.0063	34.2
0.0200%..........	51.2	0.0042	22.8
Compound C			
0.0025%..........	12.8	0.0075	40.7
0.0200%..........	19.0	0.0069	37.4
None	...	0.0086	46.2

TABLE 5—Mineral or Synthetic Oil, Static Water Drop Tests

Mineral Oil[1]	Minimum Effective Conc.
Nonylphenoxyacetic acid............	0.005%
N Oleoyl Sarcosine.................	0.005%

In Silicone Fluid[2]	Time to Failure
Nonylphenoxyacetic acid 0.0125%....	120 hr
N Oleoyl Sarcosine.................	168 hr

[1] Regal Oil B, Solvent Extracted 183 S.U.S. at 100 F. Texas Co.
[2] Versilube F50, General Electric Co.

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Rust Preventive –

(Continued From Page 18)

dicate the excellent protection against rusting under dynamic flow conditions provided by nonylphenoxyacetic acid.

Humidity Cabinet Test

In the humidity cabinet test, panel preparation was followed as described in MIL-L3150 Lubricating Oil Preservative, Medium. Mineral oil solutions of nonylphenoxyacetic acid afforded substantial protection. The test data (Table 7) indicate that above 1 percent this inhibitor is superior to a petroleum sulfonate. Combination with an equal quantity of an organic amine such as a substituted 2-heptadecenyl imidazoline results in a two to three fold increase in protection. Field experience has verified the effectivenes of nonylphenoxyacetic acid in preservative oils.

As an added advantage, when specimens protected with preservative oils containing nonylphenoxyacetic acid are degreased in chlorinated solvents, the

TABLE 6—Inhibitors in Turbine Oil*

Inhibitor and Concentration	
Nonylphenoxyacetic Acid 0.050%..................... 0.025%.....................	No Rust Trace Rust
N Oleoyl Sarcosine 0.025%.....................	No Rust
None	Heavy Rust

*ASTM D665 Turbine Oil Rusting Test, Sea Water Method B.

TABLE 7—Inhibitors in Turbine Oil, JAN H-792 Humidity Cabinet Data

Concentration Wt. %	Nonylphenoxyacetic Acid Hours to Rust		Petroleum Sulfonate Hours to Rust
0.50......	144	372*	120
1.0......	250	760*	250
2.0......	340	....	250
3.0......	300	....	260
4.0......	340	....	190
5.0......	572	....	140

*Data obtained by adding an equal weight of a substituted 2-heptadecenyl imidazoline.

tendency of the solvent to foam is reduced markedly.

Soluble Cutting Fluids Containing Nonylphenoxyacetic Acid

In soluble cutting fluids, nonylphenoxyacetic acid and its sodium salt are highly effective in preventing rusting of cast iron and steel. Small piles of steel chips on a cast iron plate were wetted with the soluble cutting fluid and allowed to stand for 16 hours at 50 percent relative humidity. At 0.5 percent in the cutting fluid concentrate, nonylphenoxyacetic acid prevents corrosion in this test when the fluid is used at a ratio of 1 to 80 in water.

Conclusions

Nonylphenoxyacetic acid is an effective corrosion inhibitor in aqueous and non-aqueous systems under static and dynamic conditions. Its compatability with hydrocarbon and synthetic liquids recommend it for further study in specific product applications such as gasoline, jet and other distillate fuels, petroleum and synthetic lubricating, circulating, instrument, cutting and preservative oils.

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2. Bigelow, Pickett and Zisman. *J Colloid Sci*, **1**, 513 (1946).
3. Bigelow, Glass and Zisman. *J Colloid Sci*, **2**, 567 (1947).
4. Baker and Zisman. *Ind Eng Chem*, **40**, 2338 (1948).
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8. W B. Jupp. *Trans Soc Naval Arch Marine Engs*, **60**, 382-93 (1952).
9. ASTM Book of Standards, Part 5 Fuels, Petroleum, Aromatic Hydrocarbons, Engine Antifreezes, 1957.
10. Private communication with Socony Mobil Laboratory.
11. Private communication with W. S. Quimby.
12. National Military Establishment Specification JAN-H-792, June 21, 1949.

DISCUSSIONS

Questions by Arthur J. Freedman, Standard Oil Company of Indiana, Whiting, Ind.:

What is the effect of pH on performance of nonylphenoxyacetic acid? If this product were used in gasoline, for example, it would come in contact with alkaline aqueous phases. Would the inhibitor be extracted and hence lost from the product? What is the effect of imidazoline alone under the conditions shown in your Table 7?

Reply by Robert M. Pines and John D. Spivack:

From studies based on the corrosion inhibiting properties of gasoline solutions containing 0.005 percent nonylphenoxyacetic acid which were extracted with 10 percent by volume of an aqueous phase, it appears that strongly alkaline solutions will remove the inhibitor from the gasoline phase. A 0.1N solution of sodium hydroxide extracts enough nonylphenoxyacetic acid so that the gasoline no longer protects the steel spindle in the dynamic immersion test. However, treatment with an aqueous solution at pH 10 or lower has no effect on the corrosion inihibiting properties of the gasoline.

The imidazoline mentioned in Table 7 protects the test specimens for 72 hours at 0.5 percent concentration in the base oil.

Question by Ivy M. Parker, Plantation Pipe Line Co., Atlanta, Ga.:

Did the analysis reported in Table 1 refer to the 70 percent technical grade? What is responsible for ash?

Reply by Robert M. Pine and John D. Spivack:

The analysis refers to the 70 percent technical material. The ash is due to the presence of a small amount of sodium nonylphenoxyacetate in the product.

Engineering Approach –

(Continued From Page 14)

rosion resistant coatings are included in instruction. Practical corrosion control as applied to preventive maintenance is carefully studied and discussed to permit a good decision on the optimum amount of surface preparation required and the coating materials to be used to achieve economical long lived protection.

Operation and maintenance of special equipment peculiar to protective coating work are studied. Attention is called to the hazards involved in the use of sandblasting equipment. Methods of measuring areas to be coated are discussed and the men are trained to make cost estimates.

All classroom work is followed up by field demonstrations, instructions and careful supervision. Specialization in the department is avoided and every man is trained to do the various jobs in the corrosion control program.

Results of special investigations of hazards involved in the use of flammable coating materials, solvents, sandblasting in hazardous areas and damage to equipment are presented to all department personnel in special training sessions.

Coating manufacturers and equipment distributors contribute to the program by furnishing training films and giving lectures concerning various phases of the work.

An effort is made to sell all men in the department that the proper preparation and application of corrosion resistant coatings is a highly skilled undertaking, a job in which they should be justifiably proud. The men are then receptive to ideas and suggestions covering the peculiar techniques of their job.

Parts 3 and 4 will appear in the February issue.

Abstract

A general discussion of material selection problems involved in the design of rocket engines. Stress is placed on the necessity for cleanliness and avoidance of incidental contamination of components. Some examples of specific explosion hazards are given.   6.1

Corrosion Considerations in Selection of Rocket Engine Materials*

SPACE AGE requires materials which are light in weight and corrosion resistant to a variety of aggressive environments. This is true especially in missile engine systems where they are subject to extreme corrosion from chemically corrosive propellants at high and low temperatures.

Rocket engine components must be completely compatible with propellants in use in order to have high degree of reliability. Corrosion rates of metals in contact with the propellants should be less than 1 mil/year. Non-metallics used for lip seals, o-rings, gaskets and such should not be softened, hardened, swelled, embrittled or in any way attacked by the propellants. Lubricants also must be completely compatible.

It is convenient to discuss propellants in terms of oxidizers and fuels. Oxidizers are a class of substances usually neutral to acidic in nature and very strong in oxidizing power (electro negativity). In general, oxidizers offer much more serious corrosion problems than fuels. Cleanliness is essential for oxidizer systems because, if surfaces for oxidizer service are contaminated with organic matter such as hydrocarbon greases or oils, fire or explosions may result which can burn or rupture the encasing material.

Liquid oxygen and kerosene fuel systems probably have been studied more than others. Materials suitable for liquid oxygen service must be capable of functioning properly at extremely low temperatures (cryogenic properties) as well as being non-impact sensitive when in contact with the liquid oxygen. Because hydrocarbon greases tend to explode when exposed to liquid oxygen and shock, silicone greases and halogenated oils have been found more satisfactory. While fluorinated greases and oils are non-impact sensitive, their lubrication properties are poor and they are corrosive to some alloys.

Nitrogen tetroxide presents serious corrosion and compatibility problems in the selection of metals and non-metals. These problems can be aggravated further if moisture is absorbed because nitric and nitrous acids are formed. Most stainless steels and low alloy aluminums are compatible with nitrogen tetroxide. Ordinary steel is compatible if moisture content is less than 0.1 percent. Brass, bronze, cadmium and zinc are severely corroded in tetroxide but copper silver, nickel and Monel are only mildly affected.

Polytetrafluoroethylene is the only known polymeric material capable of retaining its properties in nitrogen tetroxide for long periods. Polyester plastics and natural rubbers are severely attack. Polyethylenes become brittle after several weeks and unplasticized polychlorotrifluoroethylene softens after four hours' exposure.

Although red fuming nitric acid is considerably more corrosive to materials than nitrogen tetroxide, inhibitors can be added to it to reduce its corrosivity. Generally, inhibited RFNA is compatible with the same materials as nitrogen tetroxide.

Liquid fluorine is the most powerful oxidizing agent the chemist can prepare. At the present no plastics can be exposed to liquid fluorine flow without burning. While many metals are compatible with fluorine, they must be meticulously cleaned and stabilized before exposure to liquid fluorine. Stabilization (passivation) is a process by which materials are exposed to gaseous fluorine. An adherent fluoride film forms on the metal surface which makes it chemically inactive. Nickel, and the alloys Monel and Inconel are the most corrosion resistant materials for fluorine service. Stainless steels and many aluminum alloys also are satisfactory. Soft metals such as copper and aluminum are commonly used gasket materials because there are no suitable organic materials for this purpose.

Highly concentrated hydrogen peroxide long has been used for rocket and torpedo propulsion. It can be used as a mono-propellant or in a bi-propellant combination with almost any fuel. Ninety percent H_2O_2 solutions catalytically decompose at a temperature of about 1360 F, and each volume of liquid gives about 5000 volumes of gas (steam and oxygen).

A major difficulty in choosing materials for use with H_2O_2 is the fact that many have a catalytic effect on hydrogen peroxide. Silver, platinum, manganese, gold, copper, zinc, cadmium, lead, nickel and their alloys are among the many metals that cause catalytic decomposition of H_2O_2. Very violent explosions have occurred when H_2O_2 has been enclosed in unvented containers. High purity aluminum and specially passivated AISI 300 series stainless steels are commonly used for containing and handling H_2O_2. Ordinary steels are severely rusted by it. Chromium may be leached from certain alloys causing instability of the solution and poisoning of catalysts in decomposition chambers. Even high purity aluminum often is severely corroded. Aluminum corrosion products are not catalytic.

High purity of the H_2O_2 is of utmost importance in preventing corrosion and preserving stability. Very small amounts of chloride ion have caused extreme corrosion of aluminum shipping drums. Corrosion products such as rust from pressurizing lines have been known to cause explosions when decomposition became too rapid for relief by venting.

For incompatible metals, organic materials such as epoxy resins, polyethylene and other hydrocarbon derivatives have been evaluated as protective coatings against hydrogen peroxide vapors. Failure occurs first in blistering of the epoxies or penetration of polyethylene and destruction of the bond between the metal substrate and the coating. One satisfactory coal tar derived coating behaves as a fuel at high temperatures.

Fuels are a class of substances which usually are neutral to slightly alkaline in nature and sometimes possess weak reducing properties. While common fuels are compatible with many materials they present substantial problems in the selection of compatible non-metallic missile components. Many problems with seals, o-rings, lubricants, etc., are the result of the solvency power of the fuels. Swelling, softening, hardening, disintegration and embrittlement are effects commonly encountered.

Petroleum-based fuels such as kerosene, cause negligible corrosion of metals but seals and o-rings must be resistant to their solvency. Buna N and fluorinated silicones satisfactorily resist their swelling and softening tendency.

Hydrazine, an alkaline compound with some reducing properties, corrodes low alloy steels, lead, zinc, electroless nickel and cadmium. Although it is compatible with most stainless steels and low alloy aluminum materials, stainless steels containing more than 0.5 molybdenum are not satisfactory because molybdenum and its corrosion products are catalytic towards hydrazine decomposition at elevated temperatures. The literature has reported incidents of explosions when stainless steels high in molybdenum content came in contact with hydrazine at elevated temperatures. The exact nature of the reaction is unknown.

Polytetrafluoroethylene, polyethlene, unplasticized polychlorotrifluoroethylene, nylon, and some butyl rubbers are compatible with hydrazine. Hexafluoropropylene-vinyllidene fluoride, fluorosilicone, polychlorotrifluoroethylene elastomer, neoprene and Buna N are affected adversely in that they dissolve, disintegrate, blister or swell in the liquid.

Unsymmetrical dimethyl hydrazine (UDMH) affects materials in a manner similar but not quite as severely as hydrazine. A notable exception is the good compatibility of low alloy steels with UDMH.

Liquid anhydrous ammonia will not affect most metals including copper and silver and their alloys, but ammonia containing only 300 ppm water will corrode copper and its alloys and probably silver. Low alloy steels, stainless steels and aluminum are usable. Compatible non-metallics include asbestos, carbon, nylon and some natural rubbers. Most fluorocarbons are embrittled when exposed to NH_3 for very long periods.

It is apparent that propellants present serious corrosion and compatibility threats to the various components in a rocket engine system. Proper selection of materials must be based not only on temperature, stress and weight requirements, but corrosion-resistance to the propellants as well.

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Western Canadian Conference to Be Feb. 10-12

The 1960 Conference of the Canadian Region's Western Division will be February 10-12 at the Hotel Georgia in Vancouver, British Columbia. Eighteen technical papers on corrosion control will be presented during the conference.

The technical program has been designed to meet the interests of industries in Western Canada and the northwestern United States.

Registration Information
Registration will begin on Tuesday, February 9 from 1:30 to 8 pm and continue all day February 10 and 11. Registration for NACE members will be $22.50, $7.50 for ladies and $25 for non-members.

Tentative Program
Technical papers scheduled for presentation are given below.

Wednesday, February 10
General Session:
1. Fundamentals of Fresh Water Corrosion, by T. E. Larson, Illinois State Water Survey, Urbana, Ill.
2. A Corrosion Maintenance Program in an Oil Refinery, by K. Jones, Shell Oil Company of Canada, Ltd., Vancouver, B. C.
3. Paper to be scheduled later.

Protective Coatings Session:
1. Surface Preparation for Protective Coatings, by N. Tune, Los Angeles Department of Water and Power, Los Angeles, Cal.

Discusses six methods of surface preparation: solvent or vapor cleaning, hand tool cleaning, power tool cleaning, flame cleaning, chemical cleaning and sand or grit blast cleaning.

2. Evaluation of Maintenance Coating Materials Used in the Pulp and Paper Industry, by R. Nickells, B. A. Paint Co., Victoria, B. C.

Describes exposure of various coating materials to corrosive liquors found in pulp and paper industry to simulate actual conditions in the mills. Comparisons of currently used coatings are made and several new types of paints are discussed.

3. Paints for Ship Bottoms, by J. R. Brown, Pacific Naval Laboratory, Esquimalt, B. C.

Thursday, February 11
Pulp and Paper Session:
1. Experiences in Weld Overlay Techniques in Pulp Digesters, by H. Rienoff, Alloy Cladding Co., Inc., Baltimore, Md.

Methods of application, materials used and results obtained in a large number of digesters are discussed.

2. Weyerhaeuser's Experience With Kraft Digester Weld Overlay, by C. L. Carns, Weyerhaeuser Timber Co., Longview, Wash.
3. Some Aspects of Corrosion in Stainless Steel Sulfite Digesters, W. M. Scott, Columbia Cellulose Co., Ltd., Port Edwards, B. C.

Cathodic Protection Session:
1. A Discussion of One Utility's Ex-

perience of Corrosion on Anchor Rods and Steel Towers, by Rodney V. Moorman, Bonneville Power Administration, Portland, Ore.

Discusses one utility company's experience of corrosion on anchor rods and steel towers. Describes testing procedures and prevention methods. Explains development of field tests and results of several corrosion surveys. Approximately 1200 towers were investigated.

2. Corrosion Mitigation in and on a Major Gas Pipeline, by J. Stewart, Westcoast Transmission Co., Ltd., Vancouver, B. C.

Deals with measures taken to protect internal piping surfaces, results of test programs and installation of cathodic protection.

3. Cathodic Protection of Ships Hulls, by J. A. H. Carson, Pacific Naval Laboratory, Esquimalt, B. C.
4. Cathodic Protection in Fresh Water, by M. F. W. Hewes, Canadian Protective Coating, Ltd., Edmonton, Alberta.

Friday, February 12
Pulp and Paper Session:
1. Use of Nickel-Containing Alloys in Kraft Pulping, by A. Tuttle, International Nickel Company of Canada Ltd., Vancouver, B. C.

Reviews Kraft pulping process from aspect of choice of materials of construction. Emphasizes process equipment that has given problems in material performance and discusses nickel-containing alloys as means of solving these problems.

2. Use of Acid-Proof Brick and Tile to Combat Corrosion in the Pulp and Paper Industry, by L. Publicover, Stebbins Engineering and Mfg. Co., Ltd., Vancouver, B. C.
3. Material Evaluation for a Recovery Gas Scrubber, by T. Firestone, Weyerhaeuser Timber Co., Everett, Wash.

Protective Coatings Session:
1. Use of Gilsonite Products for Insulation and Corrosion Protection of Buried Hot Lines, by J. H. Henderson, American Gilsonite Co., Salt Lake City, Utah.
2. High-Build Epoxy Resin Coatings, by J. R. Gray, Shell Oil Company of Canada, Ltd., Toronto, Ontario.
3. Recent Developments in Mitigation of Underground Corrosion, by J. R. Grey, B. C. Electric Co., Vancouver, B. C.
Field Trip to Hooker Electrochemical Company plant.

Entertainment and Officers
Conference entertainment will include a Fellowship Hour at 5 pm on Thursday, February 11, followed by the Annual Banquet at 6:30.

General chairman for the conference is J. J. McLaughlin of Industrial Coatings, Ltd. Program chairman is B. H. Levelton of the British Columbia Research Council. Other committee officers are Harrison Townsend, publicity; J. R. Grey, displays; D. M. Allan, finances; N. Burnett, hotel and housing; and J. S. Whitton, registration.

Hudson   Cohen

Hudson and Cohen To Receive NACE Awards at Dallas

J. C. Hudson will be the fourth citizen of England to receive an award from NACE when awards are presented March 16 during the 16th Annual NACE Conference in Dallas. The Frank Newman Speller Award will be given to Mr. Hudson then. Morris Cohen will receive the William Rodney Whitney Award, the first Canadian to be so honored.

Other British citizens were honored with the Willis Rodney Whitney Award as follows: Ulick R. Evans (1947); W.H.J. Vernon (1954); T. P. Hoar (1957).

The two NACE awards are named after their original recipients who received the awards in 1946.

Dr. Hudson is affiliated with the British Iron and Steel Research Association, London, England. He was educated at Brighton College and the Royal College of Science. He was an investigator for the Atmospheric Corrosion Sub-Committee of the British Non-Ferrous Metals Research Association. His work there in conducting outdoor exposure tests was published by the Faraday Society and formed the basis of a thesis for which he was awarded a doctorate in science from London University. He was an investigator for the Corrosion Committee of the Iron and Steel Institute and continued in that capacity when the committee was taken over by the British Iron and Steel Research Association.

His publications include two books: Corrosion of Iron and Steel and Protective Painting of Structural Steel.

Morris Cohen, winner of the 1959 Speller Award in Corrosion Engineering, is head of the corrosion laboratory at the Division of Applied Chemistry, National Research Council, Ottawa, Ontario, Canada, where he has been employed since 1943. He has a BA from Brandon College and an MA and PhD from the University of Toronto. His main research interests have been on

GEORGE E. BEST
President

EDWARD C. GRECO
Vice President

CHARLES G. GRIBBLE
Treasurer

New Officers and Directors To Be Installed at Dallas

George E. Best, technical adviser to the general manager of technical service, Solvay Process Division of Allied Chemical Corp., Syracuse, N. Y., has been elected president of NACE for 1960-61. Edward C. Greco, senior research chemist of the research department, United Gas Corp., Shreveport, La., was elected vice president of the association, and C. G. Gribble, Jr., district manager for Metal Goods Corp., Houston, Texas was elected treasurer.

These officers will take office on the last day of the 16th Annual NACE Conference in Dallas, March 14-18.

Also elected were three directors (three-year terms): two representing corporate members and one representing active members.

J. S. Dorsey, Southern California Gas Co., Los Angeles, Cal., and J. E. Rench, Napco Corp., Houston, Texas are the new directors representing corporate members. T. J. Maitland, American Telephone and Telegraph Co., New York, N. Y., is the new director representing active members.

President-Elect Best was NACE vice president in 1959-60. His NACE activities include membership on the Board of Directors and the Executive Committee, chairmanship of the Baltimore Section and the Northeast Region, member of technical program committees, awards committee and symposia chairman. Several of his corrosion papers have been published in CORROSION. He has been in corrosion control work for 15 years.

Vice President-Elect Greco was chairman of the NACE Technical Practices Committee for 1957-59. Other NACE offices he has filled include chairman of Technical Committee T-1, vice chairman of Technical Committee T-1K, vice chairman of the Technical Practices Committee (1955-57), chairman of symposia at the 1954 South Central Region

Conference and the 1955 NACE Annual Conference. Three of his technical articles have been published in CORROSION. He is past chairman and councilor of the Ark-La-Tex Section of the American Chemical Society, has been president of the Lousiana Academy of Sciences, state director of the American Association for the Advancement of Sciences and state director of Science Fairs which he organized in 1957.

C. G. Gribble, Jr., treasurer-elect for 1960-61, currently is on the NACE Board of Directors, representing corporate members. Active in the Houston Section, he has held most of the offices in that section including chairman in 1952. On the national level, he has been chairman of the local arrangements committee for the 1952 Annual Conference in Galveston and co-chairman for exhibits at the 1957 Annual Conference in St. Louis.

J. S. Dorsey, corrosion engineer with Southern California Gas Co., is a past chairman of the Los Angeles Section, is active in Technical Committees T-2B and T-7E and has been an officer in both committees. He was an officer on the 1958 Western Region Conference and has been engaged in corrosion control work since 1944.

J. E. Rench, vice president in charge of industrial paint sales for Napko, has been active in NACE technical committees on coatings and helped organize the first paint short course held in the Houston area. He also helped organize the Houston Coating Society and has participated in short courses sponsored by NACE.

T. J. Maitland, supervising engineer with the headquarters staff of the Long Lines Department, American Telephone and Telegraph, has been active in NACE since 1944, serving in technical committee work and in the Metropolitan New York Section. Currently he is

chairman of the Technical Practices Committee and of Technical Committees T-2B, T-4B and T-4B-1. Several of his technical papers on corrosion control work on communication cables have been published and presented at national conferences. He also has served as chairman and co-chairman of symposia on utilities at NACE national and regional meetings. Formerly, he was a faculty member in the College of Engineering at the University of New Hampshire.

President-Elect Best Joins MCA Staff in Washington

George E. Best, who will be installed as the new president of NACE on the last day of the 16th Annual Conference in Dallas, March 14-18, has joined the staff of the Manufacturing Chemists' Association, 1825 Connecticut Ave., N.W., Washington 9, D.C., as staff secretary to MCA's committees on air and water pollution abatement and chemical packaging. He will also handle special assignments.

Formerly employed by Allied Chemical Corporation, Mr. Best has 20 years' experience in the chemical industry and is a graduate of Massachusetts Institute of Technology.

He was a member of MCA's Air Pollution Abatement Committee from 1949 to 1955 and helped prepare the publication "A Rational Approach to Air Pollution Legislation."

He is a member of ACS, AIChE, NACE, American Leather Chemists' Association and the Commercial Chemical Development Association.

Hudson and Cohen—

(Continued From Page 21)

the effect of thin films on corrosion inhibition and passivity and on high temperature oxidation of iron and its alloys.

In 1948, he took a year's leave of absence to work with U. R. Evans in Cambridge, England.

Dr. Cohen is a member of the American Chemical Society, the Electrochemical Society and a fellow of the Chemical Institute of Canada.

NATIONAL and REGIONAL MEETINGS and SHORT COURSES

1960

January 17-20—Canadian Region Eastern Division. Toronto, King Edward Hotel.

February 10-12—Canadian Region Western Division. Vancouver. Hotel Georgia.

March 14-18—16th Annual Conference and 1960 Corrosion Show. Dallas, Texas, Memorial Auditorium.

Oct. 6-7—10th Annual Western Region Conference, Sheraton-Palace Hotel, San Francisco, Cal.

Oct. 6-8—Southeast Region Conference, Dinkler-Plaza Hotel, Atlanta, Ga.

Oct. 11-14—Northeast Region Conference. Prichard Hotel, Huntington, W. Va.

Oct. 19-20—North Central Region Conference. Schroeder Hotel, Milwaukee.

Oct. 25-28—South Central Region Conference, Mayo Hotel, Tulsa.

1961

March 13-17—17th Annual Conference and 1961 Corrosion Show, Buffalo, N. Y., Hotel Statler.

Oct. 4-6—Western Region Conference, Hotel Multnomah, Portland, Oregon.

Oct. 9-11—North Central Region Conference, St. Louis, Chase Park Plaza Hotel.

Oct. 24-27—South Central Region Conference, Houston, Shamrock Hotel.

Oct. 30-Nov. 2—Northeast Region Conference, New York City, Hotel Statler.

Southeast Region Conference, Miami, Fla., in conjunction with Miami Section's short course.

1962

March 18-22—18th Annual Conference and 1962 Corrosion Show. Kansas City, Municipal Auditorium.

October 9-11—North Central Region Conference.

October 16-19—South Central Region Conference, Hilton Hotel, San Antonio, Texas.

Southeast Region Conference, Birmingham, Ala.

Western Region Conference. San Diego, Cal.

SHORT COURSES

1960

January 28-29—5th Annual Houston Section 2-Day Course in Practical Corrosion Control Systems. Rice Hotel, Houston.

February 24-26—11th Annual Tulsa Section Corrosion Short Course for Pipeliners. Mayo Hotel, Tulsa, Okla.

April 27-29—Portland Section Corrosion Control Short Course.

June 1-3—5th Annual Appalachian Underground Corrosion Short Course, West Virginia University, Morgantown, W. Va.

September 28-30—Central Oklahoma Section 1960 Corrosion Control Short Course, at University of Oklahoma, Norman.

October 3-5—Corrosion Control Short Course, sponsored by Western Region and University of California.

Northeast Region

Niagara Frontier Section elected its 1960 officers at a recent meeting. They are Chairman E. K. Benson of New York Telephone Co., Buffalo, N. Y., Vice Chairman C. R. Bishop of Union Carbide Metals Co., Niagara Falls, N. Y., and Secretary-Treasurer R. E. Robinson of Hooker Chemical Corp., Niagara Falls, N. Y.

Clarence A. Weltman of Alox Corporation, Niagara Falls, was guest speaker for the November 10 dinner meeting. He discussed applications of corrosion inhibitors and the behavior of organic type compounds.

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Lehigh Valley Section heard Harold J. Looby of Albi Manufacturing Company talk on fire retardant coatings at the November 16 meeting.

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Genesee Valley Section recently elected new officers. They are Chairman John Garlock, Vice Chairman E. Grant Pike and Secretary-Treasurer Richard Saunders.

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Kanawha Valley Section had Harry Aschan of Good-All Electric Manufacturing Company, Ogallala, Neb., as guest speaker for the November 19 meeting. His subject was "Modern Rectifiers in Cathodic Protection."

Twenty-four members and seven guests were present for the September 24 meetings. Guest speakers were J. T. Burke of Nalco Chemical Company, who discussed water chemistry and treatment and A. S. Krisher of Monsanto Chemical Company, who spoke on corrosion in cooling water.

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Baltimore-Washington Section had T. J. Maitland of American Telephone and Telegraph Co., New York, N. Y., as guest speaker at the November 16 meeting. He spoke on problems, testing and mitigation methods peculiar to corrosion control of lead sheath cables in underground multiple ducts.

Pittsburgh Section's January 7 meeting will feature a talk on microbiological studies of pipeline backfilled ditches by J. O. Harris of Kansas State University's Department of Bacteriology. The meeting will be held at the Mellon Institute Conference Room.

The February 4 meeting's technical program will feature a talk by R. A. Fisher of Carnegie Institute of Technology, who will speak on modern architectural design and associated corrosion problems.

Printing Schedule Changed For NACE Directory Pages

The schedule for running directories of NACE region and section officers, corporate members and technical committee officers has been changed effective with the January 1960 issue. The change is being made to bring publication nearer to the times when the majority of officer changes take place in regions and sections and technical committees.

The revised schedule will be as follows:

Corporate Member Directory—March, June, September, December.

Region and Section Officers—February, May, August, November.

Technical Committee Officers—January, April, July, October.

NACE Central Offices Are Moved to Larger Quarters

Central Offices of the National Association of Corrosion Engineers have been moved to new and larger quarters in the M & M Building, Houston. The offices, on the same floor, will have the same number, so there will be no address change.

Surface Preparation Slide Talk Available From NACE Offices

Program committee chairmen of NACE and other organizations interested in problems associated with sandblasting steel surfaces are advised that a color slide illustrated talk is available on loan from NACE Central Office. The slide talk is based on a paper "Surface Preparation by Sandblasting," by E. W. Oakes, Clementina, Ltd., Houston given before T-6G committee during the NACE conference in Chicago, March 1959.

The talk pertains to application of specifications of the Steel Structures Painting Council to different kinds of steel surfaces. It considers the problems arising when different end results are obtained from application of the specifications to surfaces varying widely in their original condition. Clementina Company has supplied copies of data from Mr. Oakes' paper which may be made to those seeing the talk.

NACE will have three sets of slides, plus accompanying commentary and supplies of the additional printed information. There will be no fee for the use of the talk. It is prepared in such a way that anyone reasonably familiar with surface preparation problems can present it. Eighteen 35 mm slides are used.

Persons interested in presenting this slide talk may schedule its use on a first come first served basis by writing to Mr. Gil Rolak, NACE Administrative Assistant for Regions and Sections, 1061 M & M Bldg., Houston 2, Texas. Accompanying the request should be an estimate of the number of copies of printed material that will be required.

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Canadian Region's Eastern Division Conference will be held January 17-20 in Toronto.

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Canadian Region's Western Division Conference will be February 10-12 in Vancouver.

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More than 30,000 franchised retail dealers sell motor trucks in the United States.

Canadian Region

Two NACE Sections Forming in Canada

The 59th NACE section has been approved and application for approval for the 60th section has been made. Both of the new sections will be in the Canadian Region.

One section for the Saskatchewan area has been approved by the Canadian Region Board of Trustees. A specific name for the section is being worked on.

The other section is being organized in the southwestern Ontario area. Application for approval has been submitted.

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Edmonton Section elected its 1960 officers at the November 26 meeting. They are Chairman John L. Gattenmeyer of Canadian Protective Coating, Ltd., Vice Chairman David A. Hindley of Rice Engineering and Operating, Ltd., Secre-

tary-Treasurer Hugh Slater of Texaco Exploration Company, Ltd., and Trustee Malcolm W. Clarke of Canadian Protective Coating, Ltd.

F. W. Hewes of Canadian Protective Coating presented a paper on prediction, detection and prevention of corrosion on buried aluminum lines as part of the technical program.

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Hamilton-Niagara Section has reorganized and has planned its first meeting this month. Officers elected at the December meeting were as follows: Chairman L. E. Sterne of G. F. Sterne & Sons, Brantford, Ontario, Vice Chairman C. Bullick of Sarnia Products Pipeline Co., Waterdown, Ontario, Secretary J. B. Hambley of Alchem Limited, Burlington, Ontario, and Treasurer Robert Campbell of United Gas Limited, Hamilton, Ontario. Past chairman Heard Hyslop was appointed trustee and Gerry Connor was appointed membership chairman.

Houston Section Short Course Scheduled for January 28-29

Nineteen speakers have been scheduled for the two-day course in practical corrosion control systems sponsored by the Houston Section. The course will be held January 28-29 at the Rice Hotel, Houston, Texas.

First day of the course will be devoted to fundamentals of corrosion and corrosion control. The second day will include full-day sessions on corrosion control systems for five specific industries: pipelines, utilities, commercial and residential design, industrial and chemical plants and oil and gas production.

The course is designed for operating field men, supervisory personnel, engineers, technicians, architects and salesmen who are connected with the corrosion control field.

Schedule of the two-day course is given below.

First Day's Schedule

am

7-8:20 Registration

8:30-8:45 Corrosion Losses Can Be Controlled—Let's Do It!—a talk by R. A. Brannon, Humble Pipe Line Co.

8:45-9:45 Fundamentals of Corrosion and Corrosion Control, by Maurice A. Riordan, Rio Engineering Company.

10-10:30 The Nature of Corrosion—a film from International Nickel Co., Inc., Reel 1: Corrosion in Action.

10:50-11:30 Reels 2 and 3: Origin and Characteristics of Corrosion Currents; Passivity and Protective Films.

pm

1-1:50 Coating Systems for External Surfaces: Underground Coatings and Tapes, by E. Rudge Allen, Humble Pipe Line Company; Paint Systems, by H. E. Waldrip, Gulf Oil Corp.

2-2:50 Coating and Inhibitor Systems for Internal Surfaces, by L. G. Sharpe, Texas Eastern Transmission Corp., and C. C. Nathan, Texaco, Inc.

3:10-4 Fundamentals of Cathodic Protection Systems, by Maurice A. Riordan, Rio Engineering Company.

11th Annual Tulsa Short Course Set For February 24-26

Practical application of corrosion control information will be emphasized at the 11th Annual Corrosion Short Course for Pipeliners sponsored by the Tulsa Section, February 24-26. The course is designed to familiarize pipeline operating personnel including supervisors, foremen, technicians, junior engineers and others with corrosion control methods.

Short Course Schedule

Wednesday, February 24:

Introduction by Park Muir, Dowell, Inc.

Why Corrosion Control, by J. N. Hunter, Service Pipe Line Company.

Corrosion in Action: a film by International Nickel Company.

Fundamentals of Corrosion, by Orville Everett, Oklahoma Natural Gas Company.

Fundamentals of Cathodic Protection, by Orville Everett.

Measurements and Instruments for Corrosion, by Melvin Barb, Kerr McGee Oil Industries, Inc.

Thursday, February 25:

Corrosion Control Surveys, by T. L. Canfield, Cathodic Protection Service.

Cathodic Protection With Galvanic Anodes, by L. E. Maddux, Continental Pipe Line Company.

Cathodic Protection With Impressed Currents, by W. A. Hutchison, Sinclair Pipe Line Company.

Field Trip, conducted by Louis Hayward, Mid-Continent Pipe Line Company.

Banquet at Mayo Hotel.

Friday, February 26:

Use of Coatings in Corrosion Control, by Lyle Sheppard, Shell Pipe Line Company.

Coordination of Pipelining and Corrosion Control, by B. H. Davis, Gulf Refining Company.

Miscellaneous Corrosion Control Equipment, by Earl O. Owens.

Question and Answer Session, to involve all course speakers.

Registration Information

Registration desk will be in the Mayo Hotel lobby, 6-8 pm, Tuesday, February 23 and also will be open each morning during the course. Registration fee is $15, which includes one banquet ticket. Advance registrations should be sent to Mr. Brady at the above address.

Short Course Officers

Members of the planning committee for the short course are as follows: Chairman: Paul Fisher of Service Pipe Line Co. Program: Dick Walton of Royston Laboratories. Center Arrangements: Gene Donaldson of Pan American Research. Registration: Hugh Brady of Corrosion Services, Inc. Publicity: Ray Amstutz of Earlougher Engineering, Inc. Field Trip: Louis Hayward, Jr., of Mid Continent Pipe Line Co. Banquet: A. Z. Partain of Pittsburgh Coke and Chemical Co.

Schedule of Second Day's Activities at H

Sessions	8:00-8:50	9:00-9:45	10:15-11:00
Transmission Pipe Lines Systems (oil, gas and products pipe lines) M. E. Frank, chairman Tennessee Gas Pipe Line Co.	Soil Box Demonstrations Cathodic Protection Principles, by C. L. Woody, United Gas Corporation Cathodic Protection Systems, by M. E. Frank, Tennessee Gas Pipe Line Company	External Coatings for Underground Service, by E. Rudge Allen, Humble Pipe Line Co.	Internal Coatings, by L. G. Sharpe, Texas Eastern Transmission Corp. Inhibitors and Their Economics, by E. R. Allen, Humble Pipe Line Co.
Oil and Gas Production (wells, flow lines, tank interiors, heater treaters and marine) Joy J. Payton, chairman Texaco, Inc.	Soil Box Demonstrations Cathodic Protection Principles, by C. L. Woody, United Gas Corporation Cathodic Protection Systems, by M. E. Frank, Tennessee Gas Pipe Line Company	Corrosion Problems, Corrosion Detection and Corrosion Control Practices in Producing Operations, by W. A. Edwards, Superior Oil Co.	Corrosion Inhibitors, Field Application, Evaluation and Laboratory Testing, by D. R. Fincher, Tidewater Oil Co.
Refineries, Chemical, Petrochemical and Industrial Plants W. G. Ashbaugh, chairman Union Carbide Chemicals Co.	Soil Box Demonstrations Cathodic Protection Principles, by C. L. Woody, United Gas Corporation Cathodic Protection Systems, by M. E. Frank, Tennessee Gas Pipe Line Company	Application, Operation and Maintenance of Cathodic Protection in Refineries and Plants, by E. C. Winegartner, Humble Oil and Refining Co.	Metals and Alloys for Corrosive Service and High Temperature Service, by George L. Garwood, Phillips Petroleum Co.
Utilities (gas and water distribution systems, telephone and power systems) C. L. Woody, chairman United Gas Corp.	Soil Box Demonstrations Cathodic Protection Principles, by C. L. Woody, United Gas Corporation Cathodic Protection Systems, by M. E. Frank, Tennessee Gas Pipe Line Company	External Coatings for Underground Service, by E. R. Allen, Humble Pipe Line Co.	Survey, Design and Installation of Cathodic Protection Systems, by T. M. Heitman, United Gas Corp., and C. L. Mercer, Southwestern Bell Telephone Co.
Commercial and Residential Design (heating and air conditioning) M. A. Riordan, chairman Rio Engineering Co.	Soil Box Demonstrations Cathodic Protection Principles, by C. L. Woody, United Gas Corporation Cathodic Protection Systems, by M. E. Frank, Tennessee Gas Pipe Line Company	External Coatings for Underground Service, by E. R. Allen, Humble Pipe Line Co.	Survey, Design and Installation of Cathodic Protection Systems, by T. M. Heitman, United Gas Corp., and C. L. Mercer, Southwestern Bell Telephone Co.

South Central Region

Tulsa Section heard O. L. Riggs, corrosion research section group leader with Continental Oil Co., Ponca City, Okla., talk on the Anatrol system for corrosion control. Equipment used in the system was demonstrated.

East Texas Section had 28 members and guests at its November 24 meeting. Guest speaker was LeRoy DeRouen, Union Oil and Gas Corp., who spoke on concentric completion of high pressure gas and oil wells. He also discussed methods and cost of inhibitor treatment.

Alamo Section held a roundtable discussion of corrosion problems that members encountered in their work.

New section officers were elected at the November 17 meeting. They are Chairman J. C. Kneuper of City Public Service Board, Vice Chairman R. N. Dobie of the City Public Service Board and Secretary-Treasurer J. W. Gibson of the D. W. Haering Company. Joe W. Gibson spoke on water problems as part of the technical program.

Shreveport Section elected new officers at the December 1 meeting. They are Chairman R. B. Naremore, Arkansas Fuel Oil Corp., Vice Chairman Grady Howell, Tube-Kote Co., Secretary D. A. Tefankjian, Texas Eastern Transmission Corp., Treasurer Frank Therall, Interstate Oil Pipe Line Co., and Trustee Burt Irish, Irish Engineering Co.

Corpus Christi Section had a paper presented on "Effect of Atmospheric Environment on Corrosion Rates of Steel" for its November 24 meeting. Written by K. K. Moore and Marcus Grumbles, Jr., of Materials and Tests Division, Texas State Highway Department, the paper presentation also included slides shown by John Nee of Briner Paint Company.

Central Oklahoma Section had NACE

Executive Secretary T. J. Hull as guest speaker at the November 9 meeting. He spoke on new horizons for NACE as a national organization and also presented a technical paper on sandblasting written by E. W. Oakes, Clementina, Ltd., Houston, Texas.

Permian Basin Section elected its 1960 officers at a recent meeting. They are Chairman G. K. Harding of Gulf Oil Co., Goldsmith, First Vice Chairman Bob Booth of Plastic Applicators, Inc., Odessa, Second Vice Chairman Bob Weeter of Mobil Oil Co., Midland, Secretary-Treasurer A. L. Mortimer of Magna Chemical, Inc., Odessa, and Trustee Roscoe Jarmon of Permian Enterprises, Inc., Odessa.

Joe Rench of Napko, Inc., spoke on the subject "Why Coatings Ain't Paint" at the December 8 meeting.

M. A. Riordan of Rio Engineering, Houston, spoke on basic principles of corrosion and cathodic protection at the November 10 meeting.

North Texas Section heard Jack P. Barrett of Pan American Petroleum Corp., Tulsa, Okla., speak on application of plastics in the oil and gas industry at the December 14 meeting.

Western Region

San Francisco Bay Area Section has scheduled George Moller of Union Oil Oleum Refinery to present a paper detailing the application of statistical analysis to corrosion studies for the January 12 meeting.

R. C. Canapary, product manager of the Petroleum Industry Section of Nalco Chemical Company, presented a paper entitled "Filming Corrosion Inhibition in Hydrocarbon Streams" at the December 8 meeting.

Several Changes Are Made In This Issue of Corrosion

A number of changes have been made in the January issue of CORROSION designed to improve readership of the news and abstract portions and to fill long standing needs of readers and advertisers.

Most noticeable of the changes is the shifting of the Technical Section to the back of the magazine. At the same time the directories were moved to the back to preserve their relative position to the Technical Section. Technical Topics Section, which has been growing in reader interest and importance since it was established less than two years ago, has been shifted ahead of the Technical Committee Activities and NACE News sections of the magazine.

A new name has been given to what formerly was called "General" News, to make it "Record and Report" which more nearly describes the contents of the section. This section will be expanded and improved from month to month in recognition of the increased interest in it expressed by readers. Also in this section "New Products," is being improved by the addition of more readable headings.

In response to repeated requests over a long period of years, CORROSION for the first time is publishing advertising in colors on the inside of the magazine. Formerly colors were accepted only on covers and on inserts run inside the back cover.

Plans for 1960 call for a Technical Section of slightly more pages than was published in 1959. The Technical Topics Section should be substantially larger, as will the Record and Report Section.

Two additions have been made. They are an editorial page, and a page headed "This Month in Corrosion Control", both monthly features. The editorial page will permit bringing to the attention of CORROSION's readers items of interest which cannot be properly handled in news stories. This Month in Corrosion Control will serve to highlight some of the important information in every issue.

at Houston Section's Jan. 28-29 Short Course

11:10-11:55	1:00-1:50	2:00-2:30	3:00-4:00
Design, Operation and Maintenance of Cathodic Protection Systems, and Cathodic Protection Interferences, by Marshall Parker, consultant	Field Instruments and Designing for Corrosion Control, by B. J. Whitley, Tennessee Gas Pipe Line Co.	Records, Field Reports and Their Evaluation, by Sal Belassai, Transcontinental Gas Pipe Line Corp.	Round Table Discussion
Protective Coatings, Atmospheric Underground and Marine—Plastic Coated Tubing, by R. M. Robinson, Continental Oil Co.	Cathodic Protection for Production Operations—Well Casing, Tank Interiors, Heater Treaters and Offshore Structures, by J. E. Landers, Continental Oil Co.	Records and Field Reports, by Paul Barnard, Atlantic Refining Co.	Round Table Discussion
External and Internal Protective Coatings for Plant Service, by F. P. Helms, Union Carbide Chemicals Co.	Inhibitors and Chemical Treatment for Corrosion Control, by J. M. Brooke, Phillips Petroleum Corp.	Corrosion Detection Testing, Records and Field Reports, by E. C. Winegartner, Humble Oil and Refining Co.	Round Table Discussion
Operation and Maintenance of Corrosion Control Systems and Design for Corrosion Control, by T. M. Heitman, United Gas Corp., and C. L. Mercer, Southwestern Bell Telephone Co.	Field Instruments and How to Use Them in Corrosion Control of Utilities, by C. L. Woody	Records, Field Reports and Corrosion Coordinating Committees	
Operation and Maintenance of Corrosion Control Systems and Design for Corrosion Control, by T. M. Heitman, United Gas Corp., and C. L. Mercer, Southwestern Bell Telephone Co.	Inhibitors and Chemical Treatment for Corrosion Control	Records, Field Reports and Corrosion Coordinating Committees	

North Central Region

Chicago Section has its next meeting scheduled for January 19.

At the November 17 meeting, nominations for section officers were presented as follows: Chairman D. G. Keefe, Vice Chairman Wayne H. Schultz, Secretary D. B. Sheldahl and Treasurer L. L. Swan.

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Detroit Section elected its officers for 1960 at the November 19 meeting. They are Chairman Euel Vines of Koppers Company, Vice Chairman Carl Durbin of Chrysler Corporation, Treasurer Leonard Rowe of General Motors and Secretary James Everett of Truscon Laboratories. Two members-at-large were elected for two year terms: Jack Patt of Magnus Products and Andrew Spencer of Chrysler Corporation.

Walter A. Symanski was guest speaker

DEATHS

John Paul Oliver, NACE member who was employed by National Carbon Company, Cleveland, Ohio, since 1944 as an electro-chemical engineer, died on November 16. He had been an NACE member since 1947. Before joining National Carbon, he was in corrosion control work at the perchlorate plant of the Cardox Corporation at Claremore, Okla. He had a BA in chemistry from the University of Iowa.
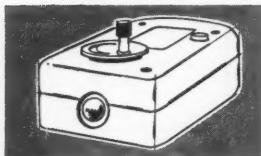
at the November 19 meeting. His topic was uses of polyester fiberglass in the chemical industry.

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Southwestern Ohio Section has appointed Sylvan Falck of Inner Tank Lining Corporation as program chairman to replace William Spurgeon, who has moved to Detroit to accept a position with the Bendix Corporation.

The 1960 North Central Region Conference will be held Oct. 19-20 at the Schroeder Hotel in Milwaukee, Wis.

Southeast Region

Arthur B. Smith Elected Southeast Region Director

Arthur B. Smith of Amercoat Corporation, Jacksonville, Fla., was elected director of the Southeast Region for 1960 in a recent election.

Other regional officers elected were as follows: Chairman George M. Jeffares, Plantation Pipe Line Co., Atlanta, Ga., Vice Chairman Henry T. Rudolf, Atlantic Coatings Co., Inc., Jacksonville, Fla., Secretary-Treasurer James L. English, Oak Ridge National Laboratory, Oak Ridge, Tenn., and Assistant Secretary-Treasurer Edwin J. Tilton, Jr., Florida Power & Light Co., Miami, Fla.

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There were 311,758 stockholders in one U. S. steel company in 1958. These stockholders included men and women from all walks of life in every state in the nation.

SECTION CALENDAR

January

4   North Texas Section.
5   Shreveport Section. Capt. Shreve Hotel.
7   West Kansas Section.
7   Pittsburgh Section. Microbiological Studies of Pipeline Back-Filled Ditches, by J. O. Harris, Kansas State University.
12 San Francisco Bay Area Section.
12 Baltimore-Washington Section.
19 Chicago Section.
20 Los Angeles Section.
21 Detroit Section. Tank Lining Forum: L. Woerner, Automotive Rubber Co., L. J Barker, Union Carbide, and W. J. Crehan, Gatz.
25 Tulsa Section.
26 Panhandle Section.
26 Southwestern Ohio Section. Corrosion Resistant and Masonry Construction, by Robert Pierce, Pennsalt Chemical Corp. To be held in Cincinnati.
28 Edmonton Section.
28 Sabine-Neches Section.

February

1   North Texas Section.
2   Shreveport Section. Capt. Shreve Hotel. Cathodic Protection—Design for Interference.
2   Philadelphia Section. Role of the Materials Engineer, by Walter Burton.
4   West Kansas Section.
4   Pittsburgh Section. Modern Architectural Design and Associated Corrosion Problems, by R. A. Fisher, Carnegie Institute of Technology.
9   Houston Section. Joint meeting with Southwest District ASTM. F. L. LaQue, International Nickel Co., Inc., ASTM president, will talk on "Research in Corrosion."
9   San Francisco Bay Area Section.
9   Montreal Section, Cement Corrosion.
16 Chicago Section. Corrosion Roundtable Discussion.
16 Baltimore-Washington Section. Corrosion Problems in Highway Maintenance, by W. J. Halstead.
18 Detroit Section. Joint Meeting with Electrochemical Society. Park Shelton Hotel. Electrochemical Mapping of Plated Surfaces, by H. T. Francis, Armour Research Foundation.
22 Tulsa Section.
23 Panhandle Section.
23 Southwestern Ohio Section. Materials of Construction in Chemical Process Industries, by Harold Boerger, Hilton Davis Chemical Co. To be held in Cincinnati.
25 Edmonton Section.
25 Sabine-Neches Section.

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Canadian Region's Eastern Division Conference will be held January 17-20 in Toronto.

ADVANCE PROGRAM
16th ANNUAL CONFERENCE
and 1960 Corrosion Show
Memorial Auditorium • Dallas, Texas • March 14-18, 1960

Outstanding Program Is Arranged

93 Technical Papers
To Be Presented

Ninety-three technical papers by 133 authors in 15 symposia have been scheduled for the 16th Annual Conference of the National Association of Corrosion Engineers. The conference will be held March 14-18 at Dallas.

Also on the technical program are meetings of 59 technical committees and of the Inter Society Corrosion Committee. Technical committee meetings will be held Monday, March 14, at the Adolphus Hotel and on succeeding days at the Dallas Municipal Auditorium. All technical symposia will be at the Municipal Auditorium.

The annual Fellowship Hour, sponsored by exhibitors at the 1960 Corrosion Show, will be held at the Adolphus on Tuesday, March 15. The annual banquet will be held on Wednesday, March 16, in the Baker Hotel ballroom. Dinner music will be furnished, and there will be a two-hour entertainment program.

The annual presentation of the Frank Newman Speller and Willis Rodney Whitney Awards and of the Young Author's Award will be made at the banquet. New officers and directors will be introduced.

At the annual general business meeting at 11 am Wednesday, March 16, in Room 300 Memorial Auditorium, actions of the NACE board will be ratified and the usual reports heard from officers and standing committees of the association.

NACE will staff a booth at the Corrosion Show where information about the program and the association may be obtained.

An advance program and other information on the Dallas Conference will be mailed early this month to NACE members and domestic subscribers of Corrosion. Hotel registration cards will be included.

1960 Corrosion Show
Has 90 Exhibitors

Hundreds of products, items of equipment and other useful information will be available to visitors at the 1960 Corrosion Show. The show, to be held from 10 am to 5 pm daily March 15-16-17 at Dallas' Municipal Auditorium, will feature the corrosion control products of 90 exhibitors to be displayed in 121 booths. Booth space for the show has been sold out since September.

Because this is the first national meeting of the National Association of Corrosion Engineers held in the Southwest in seven years, Robert W. Huff, NACE Exhibits Manager, said he believed attendance would set a record for NACE shows. The facilities at the Dallas auditorium are excellent, he said.

All technical committees meetings and symposia, as well as many other meetings of standing and special committees of the associat'on will be held in the auditorium on the floor above the corrosion show.

Although the show is not open to the public, Mr. Huff pointed out that exhibitors can obtain copies of special invitations which they may issue to their customers and friends. Previous experience indicates that a substantial number of persons will come to see the show only. There is no admission fee.

Booths are staffed by experienced scientists and engineers qualified to answer questions about their products. The usual printed technical information will be available for those interested.

Persons interested in learning more about NACE's Corrosion Shows are invited to write to Mr. Huff, at NACE Central office.

National Association of Corrosion Engineers • 1061 M & M Bldg. • Houston 2, Texas

Dallas Conference Registration Begins Sunday, March 13

No advance registration will be made for the 1960 NACE Conference in Dallas, March 14-18. Early registration will be Sunday, March 13 from 1-5 pm at the Adolphus Hotel Lobby.

Registration fee for NACE members will be $25 which will include a banquet ticket and entitles registrant to attend all conference functions. Fee for non-members will be $30 which will include a banquet ticket and admittance to all conference functions including the technical symposia, some of the technical committee meetings, Fellowship Hour and the Corrosion Show.

Fee for ladies will be $10, which will entitle the registrant to attend the banquet and all conference functions including the Ladies' Program, Fellowship Hour and the Corrosion Show.

Exhibitors at the Corrosion Show will pay no registration fee for three designated representatives. Registration fee must be paid for any other exhibitors if they wish to attend the technical symposia or technical committee meetings.

Banquet tickets must be purchased for $10 if exhibitors wish to attend.

Registration Schedules

Adolphus Hotel Lobby:
    Sunday ....1-5 pm
    Monday............7:30 am-4:30 pm
Memorial Auditorium:
    Tuesday............7:30 am-4:30 pm
    Wednesday...........8 am-4:30 pm
    Thursday.............8 am-4:30 pm
    Friday ....9-11 am

Three Educational Lectures to Be Part Of Technical Program

Three one-hour educational lectures are scheduled as part of the technical program at NACE's 16th Annual Conference, March 14-18, in Dallas.

The three lectures will be on corrosion inhibition, stress corrosion cracking and galvanic corrosion and are scheduled at 11:30 am on the three dates given below with abstracts of the three lectures.

Monday, March 14

Stress Corrosion Cracking: A Review of Current Status, by W. Lee Williams, U. S. Naval Engineering Experiment Station, Annapolis, Md.
Discusses various definitions of stress corrosion cracking used in past and attempts to clarify confusion by classifying various modes of cracking and illustrates each with typical examples. Gives the most important type of cracking as that associated with electrochemical phenomena.

Tuesday, March 15

Galvanic Corrosion, by Thomas P. May, International Nickel Company, Kure Beach-Harbor Island Testing Stations, Wrightsville Beach, N.C.
Explains that galvanic corrosion occurs when dissimilar metals are coupled in an electrolyte. Direction of galvanic current is determined by corrosion potentials of metals or alloys in the couple. Explains that intensity of galvanic corrosion depends on several factors including corrosion potentials of the metals, their susceptibility to polarization when under influence of galvanic currents, resistance of the electrolytic path, resistance of external metallic path, geometry of the system, degree of aeration of the electrolyte, etc. Underlying principles governing these factors is discussed with illustrations from studies in sea water under different conditions.

Thursday, March 17

Corrosion Inhibition, by Norman Hackerman, University of Texas, Austin, Texas
Describes recent approach to problems of corrosion inhibition by chemical addition to environment. Describes influence of molecular structure on inhibitive capacity. Explains that evidence shows all organic inhibitors to be effective in altering anodic and cathodic reactions. Experiments discussed made use of acidic solutions. Little definitive information is found on neutral solutions.

*

NACE Certificates of Membership are available from the Central Office. Measuring 5½ x 8½ inches, the certificates cost $2 each and are signed by the association president and executive secretary.

Tentative Schedule—TECHNICAL PROGRAM AND TECHNICAL COMMITTEES*

Adolphus Hotel

		Ballroom	Roof Garden	North Room	Cactus Room	Danish Room	Room A	Room D	Room G	Room C	Room B
MONDAY March 14	am	Refining Ind. Sym. Part 1 / 11:30–12:30 Educ. Lect. 1	T-2B	T-5A-1 T-5A-3	Missile Ind. Sym. Part 1	T-1	T-2J	T-6G	T-2C	T-6K	T-2L
	pm	Refining Industry Symposium Part 2	Protective Coatings Symposium Part 1	T-5A-2 T-5A	Missile Industry Sym. Part 2	T-1	T-4E-1	T-3G-1	T-9A	T-4F T-4F-1	T-2J-5

Memorial Auditorium

		Room 300	Room 303	Room 301	Room 302	Room 205	Room 200	Room 201	Room 202	Room 203	Room 204
TUEDSAY March 15	am	Chemical Industry Symposium Part 1	Protective Coatings Symposium Part 2	Oil & Gas Production Symposium	Educational Lecture, 2 11:30–12:30	T-4B T-4J	T-3G	T-3C	T-2D	T-2M	T-3F
	pm	VISIT	EXHIB	ITS	T-5D	T-4H T-4C T-4G	1961 Conference Symposium Chairmen				
WEDNESDAY March 16	am	Corr. Prin. Symposium / 11:00 Gen. Bus. Meeting	Elevated Temperature Symposium Part 1	Corrosion Inhibitors Symposium Part 1	T-6A	T-2H	T-4A	T-4E	T-2E	T-2A	T-3D
	pm	Chemical Industry Symposium Part 2	General Corrosion Symposium	Cathodic Protection Symposium	T-8A	T-5B	T-6B	T-3B T-3A	T-3H	T-6F	T-4D
THURSDAY March 17	am	Plastics Symposium Part 1	Elevated Temperature Symposium Part 2	Utilities Symposium	T-9B Educational Lecture 3 11:30–12:30	T-8	T-6E	T-3E T-3E-1	T-6R	T-6H	T-2
	pm	Plastics Symposium Part 2	Pipe Line Corrosion Symposium	High Purity Water Symposium	Corrosion Inhibitors Symposium Part 2	T-8	T-6D T-6 Adolphus Hotel Room C	T-5E T-5 Adolphus Hotel Room B	T-9 T-4 Adolphus Hotel Room F	ISCC T-3 Adolphus Hotel Room E	T-2K
FRIDAY March 18	am	General Corrosion Round Table	Pipe Line & Underground Corrosion Roundtable	Marine Corrosion Symposium							

* See pages 84 to 88 for directory of Technical Committees.

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R E P R I N T S
Of Articles Published In Corrosion

Remittances must accompany all orders for literature the aggregate cost of which is less than $5. Orders of value greater than $5 will be invoiced if requested. Add 65c per package to the prices given below for Book Post Registry to all addresses outside the United States, Canada and Mexico. Send orders and remittances to NACE, 1061 M&M Bldg., Houston 2, Texas.

Utilities Symposium Scheduled to Have 3 Technical Papers

A Utilities Industry Symposium and two roundtable discussions will be included in the 1960 NACE Conference technical program at Dallas.

One of the papers to be presented at the Utilities Industry Symposium will be "Corrosion of Tube Materials by Boiler Sludge," by D. E. White, Westinghouse Electric Corp., Pittsburgh, Pa., and E. Howells and T. A. McNary, Babcock & Wilcox, Alliance, Ohio.

Symposium chairman is C. L. Mercer, Southwestern Bell Telephone Co., Westfield, Texas. Co-chairman is A. W. MacKay, Detroit Edison Co., Detroit, Mich. The symposium will be held Thursday, March 17, 9-11:30 am.

The two roundtable discussions scheduled will be Corrosion Problems and Pipe Line and Underground Corrosion Problems. These two sessions are designed to bring together people who have specific questions on corrosion and people who can help provide the answers.

The General Corrosion Problems Roundtable will be held Friday, March 18, 9-11:30 am. Chairman is L. C. Wasson, A. O. Smith Corp., Milwaukee, Wis. Co-Chairman is John J. Halbig, Sr., Armco Steel Corp., Middletown, Ohio.

The Pipe Line and Underground Corrosion Problems Roundtable also will be held Friday, March 18, 9-11:30 am. Chairman is C. A. Erickson, Jr., Peoples Natural Gas Co., Pittsburgh, Pa.

Corporate Members to Be March 17 Luncheon Guests

All NACE corporate members are invited to a luncheon to be held Thursday, March 17, during the 1960 Dallas Conference. Each corporate member has been asked to bring a management representative from his company. Both the member and his company representative will be guests of NACE at the luncheon.

W. C. Kinsolving, vice president of Sun Pipe Line Company, Philadelphia, Pa., will give the keynote address at the luncheon.

Executives of companies in the Dallas area also are invited to attend the luncheon.

NACE Booth at Exhibition

An NACE Booth will be set up in the Exhibition Hall of the Memorial Auditorium during the Dallas Conference. Open Tuesday through Thursday, March 15-17, the booth will serve as an information center for the conference and will also have samples of all NACE literature available including the Bibliographic Survey, Abstract Card Service, literature lists and Mudd Manual.

Membership application blanks and information on 1960 regional meetings will be available at the booth. Orders is for copies of technical papers to be presented at the Dallas conference will be taken at the booth.

How to Order Papers

Improvements in the procedure for handling orders for copies of technical papers given at the Dallas Conference have been made. The revised procedure will be:

1. Orders will be taken at Dallas for copies of papers to be printed by NACE at a uniform price of 50 cents per copy, payment with order.

2. A list will be published in April CORROSION of papers to be printed by NACE. Orders will be accepted for these papers from those who attended the conference at 50¢ per copy. Orders from those who did not attend will be accepted at $1 a copy.

3. Request forms will be available at Dallas to be used to ask for copies of papers to be printed by authors themselves.

4. A list of papers not known to be available in printed form will be provided on which copies may be requested. These requests will be used only to inform authors of the number who want their papers. These requests are not expected to result in copies actually being received by those interested.

5. Order forms will be at the NACE Corrosion Show booth.

Papers ordered from NACE will be printed and forwarded within six weeks after the conference.

NACE will collect and forward to authors who choose to print their own papers, requests received for them. It will then be the responsibility of the authors concerned to honor the requests.

Ladies' Program Scheduled During Dallas Conference

Headquarters and Hospitality Room for the Ladies' Program during NACE's 16th Annual Conference in Dallas will be the French Room on the lobby floor of the Adolphus Hotel.

Registration fee for ladies will be $10, entitling the registrant to attend all conference functions including the Ladies' Program, Fellowship Hour, Banquet and Corrosion Show.

The Adolphus Hotel French Room is tentatively scheduled to be open for the following times: Sunday, March 13: 2-4:30 pm; Monday through Thursday, March 14-17, 9:30 am-4:30 pm; Friday, March 18, 9:30 am-12 noon.

A tea has been planned in the French Room for 2:30 pm Monday, March 14. A coffee-brunch and style show are scheduled at the Zodiac Room of Neiman-Marcus for 9:30 am, Tuesday, March 15.

At a luncheon scheduled Wednesday, March 16, at the Adolphus Hotel Century Room, a Bifano fur showing will be given.

The Ladies' Program also includes a trip to the Decorative Center on Thursday, March 17.

Refining Industry

Session One

Monday, March 14, 9–11:15 am

Chairman Walter Janssen, American Oil Co., Texas City, Texas
Co-Chairman F. B. Hamel, Standard Oil Company of Ohio, Cleveland, Ohio

Corrosion in a Large Diethanolamine Refinery Scrubbing System, by K. L. Moore, Tidewater Oil Co., Delaware City, Del.
Describes various corrosion problems in a large DEA system that removes hydrogen sulfide from refinery fuel gas, liquid propane-propylene and desulfurizer re-cycle gas. Problems included localized corrosion, stress corrosion cracking and cavitation. Discusses effect of these problems on operation. Also describes methods of controlling this corrosion.

Solving Refinery Corrosion Problems with Aluminum, by Ellis D. Verink, Jr., and Frank B. Murphy, Aluminum Company of America, New Kensington, Pa.
Describes qualities and characteristics of aluminum which make it suitable for corrosion control in refinery atmospheres and exposures. Typical uses include heat exchanger tubes, tankage and equipment, general metal work, transportation equipment and petrochemical processing equipment.

Estimating the Cost of Corrosion in Refinery Crude Units, by Norris J. Landis, Standard Oil Company of Ohio, Cleveland, Ohio.
Describes program to estimate corrosion cost on a refinery crude oil distillation units on a unit throughput basis. Capital, maintenance and operating costs are considered. Results showed actual cost of corrosion was far less than prior estimates. Methods of gathering and analyzing various types of cost data are given and could be applicable in corrosion cost studies for all types of process units.

Missile Industry

Session One

Monday, March 14, 9–11:30 am

Chairman Nobel Ida., Martin Co., Denver, Colo.
Co-Chairman Edson H. Phelps, U. S. Steel Corp., Monroeville, Pa.

Corrosion of Materials by Fluorine and Liquid Oxygen, by F. W. Fink and Earl L. White, Battelle Memorial Institute, Columbus, Ohio.
Summarizes corrosion behavior of liquid fluorine and liquid oxygen used as rocket propellant on construction materials. Discusses compatibility of these oxidizers of alloys of iron, nickel, copper, aluminum, magnesium, titanium and zirconium. Gives corrosion rate data from published and unpublished sources. Also reviews compatibility of non-metals and organic materials. Covers effect of initiating rapid reactions or burning of metals and organic materials by compressive impact, tensile impact, friction, wear and other mechanisms.

Corrosion in Rocketry, by E. J. Kinsley, Bell Aircraft Corp., Buffalo, N.Y.
Describes types of corrosion experienced by use of various metals in direct contact with liquid rocket propellants. Also discusses methods of selection and pre-treating to combat such corrosion. Case histories are used for demonstrative purposes. Experimental procedures are given for selecting coatings and plastics for protecting missiles and aircraft against corrosion by liquid propellants. Discusses major factors in processing metal tanks for storage of inhibited red fuming nitric acid. Also gives results of storing the acid in metallic tanks at two different temperatures for various periods.

Compatibility of Materials With Unsymmetrical Dimethyl Hydrazine Rocket Fuel, by Paul Derr, Food Machinery and Chemical Corp., New York, N.Y., and Charles W. Raleigh, Food Machinery and Chemical Corp., Buffalo, N.Y.
Summarizes laboratory tests on compatibility of metals, elastomers and plastics with unsymmetrical dimethyl hydrazine. Also gives six-year history of materials service in plant production. Elastomers and plastics which were compatible included butyl rubbers, Hydropol-T, Teflon, unplasticized Kel-F and polyethylene.

Corrosion Detection Techniques as They Apply to Missiles in Silo Storage, by Leo E. Gatzek, Ramo-Woolridge Corp., Los Angeles, Cal.
Detecting techniques used to protect missiles in silo storage must detect corrosion before any damage

is done to the missile and must accumulate or integrate total exposure to corrosive conditions experienced by missile during weeks, monhs and even years that it is in storage. Diverse sources of corrosion, types of corrosion, and methods of detection are discussed.

Refining Industry

Session Two

Monday, March 14, 2–4:30 pm

Influence of Chromium Content on High Temperature Sulfidic Corrosion of Chromium Steels, by Andrew Dravnieks and A. S. Couper, Standard Oil Company (Indiana), Whiting, Ind.
Discusses use of chromium alloys to combat high temperature sulfidic corrosion in refining processes. Required chromium content for adequate corrosion resistance depends on quantity and chemical form of sulfur, temperature, pressure and particular refining process involved. Data from literature, laboratory and plant tests are correlated show effect of these variables on corrosion of chrome steels. Plant experience is given to show that slight changes in process or chromium content have caused considerable increase in corrosion rates of alloys that previous experience indicated to be safe.

High Temperature Furnace Corrosion, by R. D. Merrick, Esso Research and Engineering Co., Linden, N.J.
Severe corrosion has occurred on external surface of tubes and tube supports of 25 Cr-12 Ni alloy steel in furnace operating at metal temperatures from 1600 to 2100 F. Corrosion to ½-inch depth has occurred in six weeks. Furnace was operating under normal firing conditions with little sulfur in gas. Investigation shows metal loss of furnace parts was accelerated by contaminants fluxing the hot metal surfaces.

Corrosion of Stainless Steels by Hot Hydrogen Sulfide, by F. J. Bruns, Sinclair Refining Co., Harvey, Ill.
Describes effects of welding, heat-treatment and composition on corrosion rates of various grades of stainless steel exposed to 615 F hydrogen-hydrogen sulfide stream in a commercial desulfurized. Study was made by weight loss measurements and metallographic examinations.

Controlling Corrosion While Chemical Cleaning, by Charles M. Loucks, Materials and Methods, Inc., Westlake, Ohio.
Discusses chemical properties of deposits to be removed and solvents commonly used. Corrosion characteristics of solvents are evaluated by exposing metal coupons. Undissolved deposit phases and dissolved rection products in solvent phase can alter the corrosion problem. In field applications, these conditions must be anticipated.

Protective Coatings

Session One

Monday, March 14, 2–4:30 pm

Chairman R. E. Gackenbach, American Cyanamid Co., New York, N. Y.
Co-Chairman Newell B. Casdorph, Union Carbide Chemicals Co., Port Lavaca, Texas

Inorganic Zinc Coatings, by F. Parker Helms, Union Carbide Chemicals Co., Texas City, Texas
Gives an non-technical discussion on inorganic zinc coatings and presents experience records from extensive field work and applications. Explains that protection for steel in corrosive atmospheres is obtained by incorporating inorganic zinc into a chemically resistant coating system which gives considerable savings because of reduced maintenance costs and extended service life.

Characteristics of Coal Tar-Epoxy Resin Coatings, by N. T. Shideler and F. C. Whittier, Pittsburgh Coke and Chemical Co., Pittsburgh, Pa.
Describes characteristics achieved with blending of coal tar or coal tar pitch and diepoxy resins. Chemical resistance of epoxies is reduced, but chemical resistance of coal tar is improved. Actual hardness, flexibility and underwater adhesion of the combination is better than for either of the two elements alone. Heat sensitivity of coal tars is almost eliminated in the combination. Also discusses applications for this type coating.

Vinyl-Alkyd Type Protective Coatings, by Austin K. Long, Glidden Company, Cleveland, Ohio
Gives detailed description of vinyl-alky type coating. Also discusses many variations in formulation

which are possible. Gives general characteristics including main advantages and limitations. Types of applications and usages will be covered.

Hypalon-Based Coatings, by F. J. Ploederl, Wisconsin Protective Coating Co., Green Bay, Wis.

Missile Industry

Session Two

Monday, March 14, 2–4:30 pm

Some Aspects of Corrosion in Mg-Th and Aluminum Alloys Used in the Titan ICBM, by J. Parmentier and R. Agricola, Martin Company, Denver, Colo.
Use of magnesium-thorium and high strength copper bearing aluminum alloys in the missile industry created many new corrosion protection problems. Research programs begun in attempts to solve the problems included artificial and environmental exposure of stressed and unstressed 2014-T6 aluminum protected by various methods, artificial and environmental exposure of fastened and unfastened Mg-Th alloy protected by various methods, and analysis of exposed material by macroscopic, microscopic and mechanical means.

Stress Corrosion of Steels for Aircraft and Missiles, by E. H. Phelps and A. W. Loginow, U. S. Steel Corp., Monroeville, Pa.
Results of atmospheric stress corrosion tests on alloys and stainless steel for high speed aircraft and missiles showed that high strength alloys hardened by heat-treatment are susceptible under certain conditions to stress corrosion cracking. Tempering at temperatures of 1100 F and above confers resistance to stress corrosion. Austenitic stainless steels hardened by cold working are not susceptible. Results of experiments on mechanism of cracking indicate that stress corrosion in a 12 percent martensitic stainless steel heat-treated to a very high strength is result of corrosion along an active path in the metal and is not result of hydrogen induced in metal by corrosion.

Problems Arising in Corrosion Tests for Sandwich Type Construction, by J. E. Halkias, Convair Division, General Dynamics Corp., Fort Worth, Texas
Present problems encountered in systematic corrosion test program for evaluating honeycomb sandwich type construction for airframes. Merits and limitations of salt spray, humidity, immersion and alternate wetting-heating-cooling tests are discussed. Test specimen configurations are given in drawings. Also discusses plans for correlating accelerated corrosion test data with results of long-range weathering tests and service life of sandwich panels on airplanes.

Kinetics of Hydrazine Decomposition, by Max S. Robinson, Martin Co., Denver, Colo.
Discusses test procedure for evaluating effect of various materials on decomposition of hydrazine. Reaction was conducted in an isothermal, constant volume stainless steel bomb fitted with pressure and temperature sensing elements. Data analysis indicated decomposition reaction rate was first order. In stainless steel, rolled aluminum sheet and anodized aluminum, first order rate constant ranged from 0.005 to 0.009 min. In aluminum extrusion and a fusion built weld, rate constant was increased to 0.145 sec. Data indicated that hydrazine decomposition reaction is catalytic and influenced by material present.

Chemical Industry

Session One

Tuesday, March 15, 9–11:30 am

Chairman L. W. Gleekman, Wyandotte Chemicals Corp., Wyandotte, Mich.
Co-Chairman Otto H. Fenner, Monsanto Chemical Co., St. Louis, Mo.

Intergranular Corrosion of Commercially Pure Zirconium, by D. K. Priest and B. S. Payne, Pfaudler Company, Rochester, N.Y.
Selective corrosion in a hot hydrochloric acid service was noted in a narrow band of the heat affected zone of a commercially fabricated zirconium weldment. Little attack was on the weld or parent stock. Selective attack has been found to be intergranular in nature and associated with presence of precipitated phase in grain boundaries. Microstructure required for this attack has been duplicated in bulk

Chemical Industry —

(Continued From Page 36)

samples by specific heat treatment. Corrosion rates on samples and the critical heat treatment and microstructure for excessive corrosion have been determined. Two methods of preventing this localized attack near welds have been evaluated. Also discusses possible mechanisms for microstructural changes and for the corrosion attack.

Discussion of Corrosion Problems in a Synthetic Rubber Plant, by Nick Monsour, Polymer Corporation, Ltd., Sarnia, Ontario, Canada.
Explains that many corrosive fluids such as low pressure steam and water are required in manufacture of synthetic rubber. Experience in control of these corrosive fluids is described in detail.

Trowelable Coatings for Corrosion Protection, by J. H. Cogshall and Allen M. Smith, Pennsalt Chemical Corp., Natrona, Pa.
Discusses various coatings such as epoxies, polyesters and phenolics and their application as coatings for concrete. Also describes briefly some new possibilities such as irradiation protection, linings for pipes and vessels, conductive formulations and dielectric resistance.

Protective Coatings

Session Two

Tuesday, March 15, 9–11:30 am

Laboratory Testing of Spray Applied Lining Materials, by R. S. Foster, Dow Chemical Co., Freeport, Texas.

The How, the Why, the Cost of White Sandblasting, by Henry T. Rudolf, Atlantic Coating Co., Jacksonville, Fla.
Describes techniques, equipment and costs of abrasive blasting. Topics discussed include optimum ratio of sand weight to air volume, logic of sand sizing and its bearing on efficiency of operation, how and why sandblasting cleans, how to sandblast and relative costs of blasting different types of surfaces.

Mastics, by F. M. Kennedy, Jr., Palladium Mastic Corporation of America, Rutherford, N. J.

Application Tolerance of Protective Coatings, by M. L. Monack, J. R. Allen and F. W. Thompson, E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.
Describes a study made to determine quantitatively the ability of coatings to be applied easily in a film of good integrity. Also describes equipment used for this measurement and presents results obtained on several commonly used coatings. Explains that good film-build and low viscosity as deposited are two keys to good application. Good film-build does not guarantee good film continuity, but good tolerance is almost impossible without it.

Oil and Gas Production

Tuesday, March 15, 9–11:30 am

Chairman W. C. Koger, Cities Service Oil Co., Bartlesville, Okla.
Co-Chairman J. A. Caldwell, Humble Oil & Refining Co., Houston, Texas

Corrosion Problems in the Use of Dense Salt Solutions as Packer Fluids, by C. M. Hudgins, J. E. Landers and W. D. Greathouse, Continental Oil Co., Ponca City, Okla.
Describes corrosion problems arising from use of dense salt solutions as packer fluids. Study given of corrosion characteristics of variety of systems capable of densities greater than 10 pounds per gallon. Test coupons and tubing segments of several materials were used. Salts studied included $NaNO_3$, $CaCl_2$, $CA(NO_3)_2$, $NaCl$, $ZnCl_2$, $NaNO_3 — CaCl_2$, $Ca(NO_3)_2 — CaCl_2$ and $CaCl_2 — ZnCl_2$.

Stress Corrosion Cracking in Concentrated Sodium Nitrate Solutions, by R. L. McGlasson, W. D. Greathouse and C. M. Hudgins, Continental Oil Co., Ponca City, Okla.
Discusses problem of stress corrosion cracking in oil country tubing exposed to concentrated sodium nitrate solutions used for completion fluids. Describes laboratory tests using a notched C-ring stressed with a cadmium plated, mild steel bolt. Variety of conditions were also used. Most tests were made on API tubing steels, but results are considered applicable to variety of low alloy AISI steels.

Cathodic Polarization of Steel in Various Environments, by Al Erben and R. A. Legault, Sun Oil Co., Dallas, Texas
Gives results of altering various experimental conditions on effectiveness of cathodically protecting steel in salt water systems. Study was designed to facilitate a more efficient application of cathodic protection to salt water handling vessels used in the oil producing industry.

Stress Corrosion Cracking of High Strength Tubular Goods, by R. S. Ladley, Phillips Petroleum Co., Bartlesville, Okla.
Describes stress corrosion cracking of N-80 and AISI 4340 tubing and N-80 and P-110 casing. Status of the cracking problem is discussed with respect to control measures available and what is needed in the future to use high strength tubular products in oil and gas well environments.

Anhydrous Ammonia Controls Vapor Space Corrosion in Unpacked Flowing Wells, by Rado Loncaric, D. R. Anthony, Fair Colvin and M. D. Folzenlogen, Atlantic Refining Co., Dallas, Texas
Cites field experience to show that anhydrous ammonia is effective, practical and economical in inhibition of vapor space casing corrosion of unpacked flowing oil wells in the West Texas-New Mexico area. Tests indicate that residual ammonia is present in sufficient concentrations to control vapor space corrosion to depths below 4000 feet. No casing leaks have developed in the most corrosive fields since the start of the inhibition program. Average cost per well per year was less than $50.

Corrosion Principles

Wednesday, March 16, 8:30–11 am

Chairman W. S. Quimby, Texaco, Inc., Beacon N. Y.
Co-Chairman C. P. Dillon, Union Carbide Chemicals Co., Charleston, W. Va.

Mixed Potential Theory of Metal Dissolution in Aqueous Acid Solutions, by A. C. Makrides, Union Carbide Metals Co., Niagara Falls, N.Y.
Discusses prediction of whether a substance is a good inhibitor for a particular metal in a specified environment if relevant electrochemical parameters are known. Study of inhibition by ferric sulfate on iron-chromium alloys showed that critical ferric ion concentration needed for protection could be predicted from critical current density required for passivity and from a knowledge of rate of mass transfer to metal-solution interface. Inference taken from results that adsorption of ferric ion, if any, was of little importance in mechanism of inhibition.

Discussion of the Possible Role of Autoreduction in Passivation of Iron, by E. E. Nelson, Socony Mobil Oil Co., Inc., Brooklyn, N.Y.
Reviews literature to show that iron as an anode can reduce ferric oxide in solution of pH to about 8.0 in what is called autoreduction reaction. Reduction is not affected by presence or absence of dissolved oxygen. Cites experimental and theoretical evidence. If ferric oxide film is assumed to be cause of passivation of iron, autoreduction is shown to be of paramount importance. Iron anode potential determines if ferric oxide film will be protective or not. Supposition is shown to give explanation of inhibitor action such as sodium nitrite and chromate.

Threshold Values on Factors Contributing to Stress Corrosion Cracking, by Henry Suss, General Electric Co., Schenectady, N. Y.
Reviews factors affecting stress corrosion cracking tendencies such as concentration of corrosive constituents, applied stresses, inclusions, residual and thermal stresses, metallurgical structure and notches or other surface defects. Results indicate impracticality of establishing threshold values. If material susceptible to stress corrosion cracking must be used, corrosion attack or surface tensile stresses must be eliminated. This can be done by design, use of protective layer or inhibitors and/or by substitution of compressive layer on surface of metal to counteract tensile stresses.

Concentration Cells and Aqueous Corrosion, by E. Schaschl and G. A. Marsh, Pure Oil Co., Crystal Lake, Ill.
Describes improved technique for continuous recording of maximum current output of concentration cells and for obtaining corrosion rates of cell electrodes over short periods. Generally, where a dissolved oxygen concentration cell competes with another, the dissolved oxygen cell takes precedence and is the current determining cell. Rust film on steel increases activity of local or physically separated dissolved oxygen cells. Cell action can be calculated by an equation developed from Fick's law of diffusion.

Elevated Temperature

Session One

Wednesday, March 16, 8:30–11 am

Chairman D. W. McDowell, Jr., International Nickel Co., Inc., New York, N. Y.
Co-Chairman David Roller, Magna Products Inc., Santa Fe Springs, Cal.

Corrosion Resistance of Dense, Impermeable Silicon Carbide, by Roy Dial, Carborundum Co., Niagara Falls, N.Y.
Discusses preparation, properties and corrosion resistance of dense, impermeable silicon carbide. Presents data from static corrosion tests made at temperatures to 1000 C in gases, molten metals, fused salts, acids and bases. This material is being used in missile, atomic reactor and industrial applications.

High Temperature Corrosion in Refinery Services, by E. N. Skinner, J. F. Mason and J. J. Moran, International Nickel Co., Inc., New York, N.Y.
Discusses corrosion phenomena likely to influence selection of materials for refinery service at elevated temperatures. Also discusses problems of oxidation, sulfidation and carburization and considers effects of condensate corrosion and residual oil ash corrosion. Explains the effect of alloying elements on physical and mechanical behavior of alloys and on their corrosion resistance at high temperatures. Outlines basic considerations for selection of suitable alloys for high temperature corrosive environments.

High Temperature Corrosion Behavior of Alloys Used in the Heat Treating Field, by George W. Wardwell, Rolock Inc., Fairfield, Conn.
Explains that in heat treating work, metals can be subjected to attack by oxidation, sulfidation, flux attack, silicon carbide dilution, molten solt corrosion, nitrogen attack and carbon attack. Discusses proper selection of alloys and other steps that can be taken to control these attacks.

High Temperature Lubrication in Reactive Atmospheres, by Robert L. Johnson, Max A. Swikert and Donald H. Buckley, National Aeronautics and Space Administration's Lewis Research Center, Cleveland, Ohio.
Explains that lubrication of metals at high temperatures is dependent on direct chemical reactions which can develop into corrosive wear, limiting usefulness of a lubrication process. Thus, under such conditions, lubrication can be considered controlled corrosion. Friction and wear data are given for various atmospheres, reactive lubricants and lubricated metals at temperatures from 75 to 1400 F. Presents examples showing importance of normal oxide films, inadequate surface reactions and excessive surface reactions (corrosive wear).

Internal Carburization and Oxidation of Nickel-Chromium Alloys in Carbon Monoxide, by B. E. Hopkinson and H. R. Copson, International Nickel Co., Inc., Bayonne, N.J.
Rate of internal carburization and oxidation attains a maximum at 1500 to 1750 F. Attack was slight at 1330 and 1830 F. Presence of carbon dioxide, water vapor and hydrogen in carbon monoxide did not significantly affect rate of penetration. Modified alloys resisted carburization and oxidation in all the atmospheres tested. Discusses mechanisms involved.

Inhibitors

Session One

Wednesday, March 16, 8:30–11 am

Chairman A. J. Freedman, National Aluminate Corp., Chicago, Ill.
Co-Chairman Donald L. Burns, Gulf Oil Co., Port Arthur, Texas

Contribution to Understanding of Corrosion Inhibition Through Experiments With Metallic Cations, by W. Roger Buck, III, and Henry Leidheiser, Jr., Virginia Institute for Scientific Research, Richmond, Va.
Explains that dissolved metals are excellent inhibitors for corrosion of other metals in acids under some conditions. Presents examples of inhibition of the anodic reaction. Inhibition of cathodic reaction is observed less often and only to a limited degree. Presents a mechanism for inhibiton of anodic reaction, based on present concept of a metal surface.

Inhibitors—

(Continued From Page 38)

Structural Effects of Organic N-Containing or S-Containing Compounds on Inhibition of Corrosion by Acids, by No:man Hackerman, University of Texas, Austin, Texas, Ray M. Hurd, and Robert R. Annand, Texas Research Associates Corp., Austin, Texas.

Presents some early results of research on possible correlation between molecular structure of certain organic compound types and their inhibiting efficiency. Compounds were two analogous series: one containing nitrogen, the other sulfur. Inhibiting inefficiencies were measured by standard weight loss measurements on steel coupons. Corrosive media were neutral brine and hot concentrated acids. Results indicate definite correlation which may be used in further research toward a more efficient inhibitor molecule.

Laboratory Investigation of Water Side Scale and Corrosion in Presence of High Process Side Temperatures, by Herman Kerst, Dearborn Chemical Co., Chicago, Ill.

Testing methods have been developed to determine scale deposition and corrosion on water side of heat exchange equipment in contact with high process side temperatures. Equipment is described and quantitative data given on effect of various types of scale and corrosion inhibitors.

Cooling Water Inhibitor Performance—Film Formation vs Film Maintenance, by P. R. Puckorius and W. J. Ryzner, Nalco Chemical Co., Chicago, Ill.

Discusses principle of film formation and maintenance by corrosion inhibitors in cooling water systems. Explains main function of continuous application of inhibitor to be for repair and replenishment of the film. Discusses method of applying this principle of rapid film formation.

Chemical Industry

Session Two
Wednesday, March 16, 2–4:30 pm

Compositional Effects in Corrosion of Type 347 and Type 316 Stainless Steel in Chemical Environments, by C. P. Dillon, Union Carbide Chemicals Co., Charleston, W. Va.

Statistical analyses by graphical technique indicates that resistance of Type 347 stainless steel to the Huey Test (boiling 65 percent nitric acid) can be increased by more stringent control of compositional limits. Similar analysis of chromium-nickel-molybdenum grades indicates that influence of specific constituents varies with environment. Performance in qualification tests of annealed materials or of sensitized extra low carbon material cannot predict general corrosion resistance in other environments. In those few isolated cases where compositional effects override process variables, optimum composition is unpredictable and must be determined empirically.

Chemical Plant Corrosion Control, by John L. Weis, Diamond Alkali Co., Pasadena, Texas.

Discusses advantages of preventive actions over corrective measures in light of practical corrosion control for a new chemical plant. Also discusses design considerations and gives several case histories of some unusual corrosion problems.

Improved Nickel-Base Alloys for Hot Sulfuric Acid Service, by Walter K. Boyd and M. E. Langston, Battelle Memorial Institute, Columbus, Ohio, and T. E. Johnson, Stainless Foundry and Engineering Co., Milwaukee, Wis.

In-Place Cleaning and Coating of Chemical Plant Piping, by William T. Theis, Internal Pipeline Maintenance Co., Odessa, Texas

Explains development of in-place cleaning and coating of chemical plant piping as developed from methods for oil and gas field equipment. Includes discussion of cleaning and coating methods with a procedure for suitable coating selection. Gives examples of in-place applied linings to reduce internal corrosion, to eliminate product contamination and to increase pipeline through-put.

- **Look for additions and changes in the 1960 Annual Conference Technical Program which will be published in the February issue of CORROSION.**

- **Hotel registration cards and copies of the advance program for the Dallas Conference will be mailed this month to NACE members and domestic subscribers of CORROSION. Other persons interested in having this material should write to NACE Central Offices, 1061 M & M Bldg., Houston 2, Texas.**

General Corrosion

Wednesday, March 16, 2–4:30 pm

Chairman W. L. Mathay, U. S. Steel Corp., Monroeville, Pa.
Co-Chairman Jerome M. Bialosky, Koppers Co., Inc., Verona, Pa.

Corrosivity of Various Atmospheric Test Sites as Measured by Specimens of Steel and Zinc, by C. P. Larrabee, U. S. Steel Corp., Monroev'lle, Pa., and O. B. Ellis, Armco Steel Corp., Middletown, Ohio.

Quantitative measurements by ASTM's Committee B-3 showed that one-year exposures in different North American atmospheres varied in corrosivity as much as 2000 times on steel and 80 times on zinc. At some sites, corrosivity toward steel varied 100 percent from one year to the next. Eight-year data are presented from 19 test sites scattered from coast to coast and from Florida to near the Arctic Circle.

Corrosion of Metals in Tropical Environments—Part 4: Wrought Iron, by C. R. Southwell, B. W. Forgeson and A. L. Alexander, U. S. Naval Research Laboratory, Washington, D. C.

Discusses corrosion of Aston process wrought iron exposed to five natural environments in the tropics. Results indicate that corrosion (measured by weight loss) in fresh water is about equal to that at mean tide and that corrosion is greatest during continuous immersion in sea water. Millscale on wrought iron accelerates pitting most severely on metal immersed continuously in the sea although to a lesser degree than structural steel similarly exposed. During early exposure, corrosion rates of wrought iron and mild steel in tropical water are about the same, but after eight years steel shows a greater weight loss. Also discusses corrosion of metallic couples of wrought iron and carbon steel in fresh water and sea water.

Development of Thin Metal Film Corrosion Indicators, by Gilson H. Rohrback and David Roller, Magna Products, Inc., Santa Fe Springs, Cal.

Reviews progress on development and use of visual and electrical thin metal film integrating corrosion detectors and indicators. Gives data on behavior of the indicators in corrosive atmospheres. Possible applications are described in addition to use to detect corrosion in packages and storage areas.

Aluminum Alloys for Handling and Storage of Petrochemicals, by E. H. Cook, Jr., R. L. Horst and W. W. Binger, Aluminum Company of America, New Kensington, Pa.

Describes evolution of laboratory studies into commercial applications for aluminum alloys in chemical and petrochemical industries. Attention is given to study of alloys handling 83 percent ammonium nitrate solutions at elevated temperatures. Includes discussion of aluminum applications in production and handling of aliphatic acids, sour crude oil, ammonia, amines, acrylonitrile, hydrogen cyanide, hydrogen peroxide, fuming nitric acid, phenol, liquids at cryogenic temperatures and high purity water. Explains that aluminum is often selected for protection of product purity, light weight and absence of catalytic action in addition to corrosion resistance.

Erosion-Corrosion Testing of Metals, by Robert L. Hadley and Harold J. Smith, General Electric Co., Louisville, Kentucky.

Work described was prompted by need for useful data relating combined effects of abrasion and corrosion on metals considered for product application. Lab device was developed to control temperature, corrosive medium and abrasion rate. Specimens were exposed for 100-hour periods to combined action of a solution and tumbling abrasives. Quantitative measurements were made of weight loss per unit of exposed area, changes in radii and frequency and depth of pitting. Such factors as effects of abrasion, corrosion, temperature, hardness, composition and microstructure were evaluated on comparative basis. Materials tested included several ferritic, martensitic, austenitic and precipitation hardening stainless steels. Results indicate need for proper balance between wear and corrosion resistance in materials considered for specific product design.

Cathodic Protection

Wednesday, March 16, 2–4:30 pm

Chairman H. C. Boone, Peoples Gas Light and Coke Co., Chicago, Ill.
Co-Chairman O. W. Everett, Oklahoma Natural Gas Co., Tulsa, Okla.

Packaged Cathodic Protection of the 1600-Mile Tape Coated Pipe Line to Florida, by E. P. Doremus and Ralph B. Pass, Cathodic Protection Service, Houston, Texas.

Discusses unusual problems encountered in design and installation of a cathodic protection system for the 1600-mile big inch pipe line system from Baton Rouge, La., to Miami, Fla. Presents coating resistance data on this first major all polyethylene tape coated pipe line taken immediately after laying and after application of cathodic protection.

Problems Encountered in Cathodically Protecting Pipe Lines Crossing Railroads, by F. L. Chatten, Pennsylvania Railroad Co., Philadelphia, Pa.

Reviews relationship of track circuits to railroad signal systems, their construction and basic requirements to conform to Interstate Commerce Commission rules. Explains need for freedom from outside influences. Also discusses testing methods to detect interference with track circuits and corrective measures which can be used. Case histories of interference are given.

Cathodic Protection in Desert Soils, by W. C. R. Whalley, Iraq Petroleum Co., London, England.

Discusses problems of protecting pipe lines in Northern Iraq and Syria where desert conditions make cathodic protection more difficult than in moist ground. Explains that potentials are erratic and variations are encountered of —0.5 volts within a few feet.

Use of Impressed Current Anodes in Cathodic Protection of Pipe Lines by W. P. Noser, Humble Pipe Line Company, Houston, Texas.

Presents views of a pipeline company on operation of various types of impressed current anode systems.

Protection of Corrosion Equipment From Damage by Transient Currents, by L. L. Swan, Illinois Bell Telephone Company, Chicago, Ill.

Discusses nature of switching and fault current transients, how they affect corrosion protection equipment and some successful methods for reducing equipment failure by these currents.

A Cable Company's Use of Impressed Anodes, by T. J. Maitland, American Telephone and Telegraph Co., New York, N. Y.

Plastics

Session One
Thursday, March 17, 9–11:30 am

Chairman J. B. Kittredge, Minnesota Mining & Manufacturing Co., St. Paul, Minn.
Co-Chairman John Delmonte, Furane Plastics, Inc., Los Angeles, Cal.

Effect on Various Curing Agents on the Corrosion Resistance of Epoxy Resins, by Ronald L. DeHoff, Shell Chemical Corp.

Deals with testing of some commonly used epoxy resin curing agent systems in various corrosive environments. Criteria for performance includes dimensional stability and flexural strength.

An Accelerated Test Procedure for Evaluation of Fiber Reinforced Resin Equipment in the Chemical Industry, by Otto H. Fenner, Monsanto Chemical Co., St. Louis, Mo.

Describes a procedure for evaluation of fiber reinforced resin as materials of construction for equipment in the chemical industry. System is based on interpretation of information obtained through comparison of percentage weights and flexural strength change curves plotted from laboratory and field exposures of multiple test coupons. A rating system is given which permits relatively precise prediction of long range performance of each fiber reinforced resin material.

Thermoplastics for Chemical Process Equipment, by Harvey E. Atkinson, E. I. du Pont de Nemours & Co., Wilmington, Del.

Failure to obtain successful use of thermoplastics for corrosion control is because of lack of adequate

Plastics —

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specification by the use and overzealous claims of the supplier who is probably unfamiliar with chemical process conditions. Discusses necessity for and methods of evaluating thermoplastics to determine suitability and specification requirements. Also covers preparation and use of specifications. Specific examples are given as examples.

Effects of Fabricating Technique on the Physical Properties of Polytetrafluorethylene and Monoclorotrifluorethylene for Corrosion and Service, by Victor G. Reiling, Modern Industrial Plastics, Inc., Dayton, Ohio.

Explains that methods and conditions of fabricating are important for proper functioning and service life of fluorocarbon materials. Also explains the usual processes of fabrication. Also gives advantages and limitations of different end-product methods, their effects on thermal and mechanical performance, methods of application for optimum service and recent developments in the art of fabricating-application to corrosion prevention.

Elevated Temperature

Session Two
Thursday, March 17, 9–11:30 am

High Temperature Corrosion Protection With Spray Metallized Coatings, by Harvey S. Miller, New England Hard Facing Co., Brookline, Mass.

Reviews methods of spraying metals from a solid state either in wire or powder form. Relates various methods of protecting materials such as plastics and non-ferrous and ferrous metals for use at temperatures above their melting point for short periods or above their rapid oxidation temperature for long periods. Temperatures discussed range from 600 to 4500 F. Brief discussion is given on the new plasma torches which have hot gas temperatures of 30,000 F, making possible the use of more exotic metals for coatings. Also will include use of sealers for porosity of sprayed metal coatings and post heat treatment or sintering with and without sealers. Specific examples will be used to illustrate the use of each type coating discussed.

Ceramic Coatings for High Temperature Service, by S. W. Bradstreet, Armour Research Foundation, Chicago, Ill.

Reviews principles which dominate attachment of a ceramic coating to variety of substrates for service in extreme thermal environments. Also discusses deficiencies and advantages of different combinations. Principles for tailoring protective coatings for refractory metals are suggested. Flame sprayed ceramic coating of potential value as a combustion catalyst is used to illustrate these principles.

Materials Problems Associated With Uncooled Rocket Nozzles, by Jesse D. Walton and C. R. Mason, Jr., Georgia Institute of Technology, Atlanta, Ga.

Brief discussion is given of thermal shock, erosion and catastrophic corrosion problems connected with uncooled rocket nozzles used with solid fuels. Describes materials and methods used to solve these problems in research at Georgia Tech. This approach is to use slip cast fused silica as a base material and to provide erosion and corrosion resistance in throat area with arc sprayed coating on shells. Nozzle fabrication techniques also are given. Testing and forming methods and test results are given.

Ablation Behavior of Materials Subjected to Missile Re-Entry Heat Flux Rates, by R. M. Krupka and D. E. Taylor, University of Chicago, Chicago, Ill.

Extremely high heat flux rates during re-entry of hypersonic vehicles have been simulated with the plasma discharge from high intensity, air stabilized electric arcs of approximately 1000-kw power rating. Describes behavior of samples of ten different materials tested, including four metals, three ceramics, two plastics and graphite. Gives ablation rates, heat balances and effective heats of ablation. In highest temperature test environment used, plastic and graphite samples had lower stagnation point weight loss rates during ablation than metal and ceramic samples.

High Temperature Evaluation of Thermal Protective Systems, by D. W. Gates, U. S. Army Ballistic Missile Agency, Redstone Arsenal, Ala.

Discusses methods and characteristics of heat absorption and some of the related material properties in missiles. Outlines requirements for design of materials as concerns some combinations of properties. System of correlation of various heat flux input used in testing is presentd with general descriptions of methods of heat protection. Describes problems in testing in which many factors to be evaluated are partially unknown or impossible to duplicate in the laboratory. Problem was to obtain data which will be a result of more severe testing than the material is likely to encounter.

Plastics

Session Two
Thursday, March 17, 2–4:30 pm

The Why and How of ASTM Committee D-20 on Plastics, by R. M. Berg, Union Carbide Chemicals Co., South Charleston, W. Va.

Describes activities of the ASTM Committee D-20 on Plastics. Explains that producers and consumers are represented. Current specifications and methods work include several plastics of probable interest to corrosion engineers and personnel involved in corrosion control work.

A Decade of Experience With Plastic Structures and Corrosive Environments, by Joseph L. Huscher, Kaykor Industries, Inc., Wardville, N. J.

Plastics From the Equipment Manufacturing Standpoint, by R. McFarland, Hills-McCanna Co., Chicago, Ill.

Gives resume of raw material suppliers' manufacturing problems encountered in application of corrosion resistant plastics to equipment.

Chemical Resistance of Plastics as Influenced by Thermal Stability, by William Dewar and John Delmonte, Furane Plastics, Inc., Los Angeles, Cal.

Pipe Line General

Thursday, March 17, 2–4:30 pm

Chairman George M. Jeffares. Plantation Pipe Line Co., Atlanta, Ga.

Co-Chairman C. L. Goodwin, Portland Pipeline Corp., Portland, Maine

Protection of New Gas Lines Bringing Natural Gas to Florida, by Joseph S. Frink, Houston Corp., Miami, Fla.

Soil Bacteria in Relation to Cathodic Protection, by John O. Harris, Kansas State University, Manhattan, Kan.

Describes project designed to learn whether soil micro-organisms could alter the insulating value of coatings used on pipe lines. Findings indicate that many types of bacteria can grow on straight-chain hydrocarbons. Field studies show that pipeline ditch furnishes favorable environment for microbial development. Discusses significance of these data in relation to cathodic protection of pipe lines.

Report on Progress of NACE Technical Group Committee T-2 Task Group on Minimum Requirements for Protection of Buried Steel Pipe Lines, by W. H. Stewart, Sun Pipe Line Co., Beaumont, Texas

Gives report on progress of NACE's T-2 Task Group on Minimum Requirements for Protection of Buried Steel Pipe Lines. Requirements were established as a base from which further design or improvements could be made. Emphasizes that "minimum requirements" as given in report are not "standards or specifications." When completed, task group report will include requirements on asphalt coatings, coal tar coatings, shields, wrappers and cathodic protection.

Corrosion Takes Toll on 28-Year-Old Transmission Main, by John Van Bladeren, Northwest Natural Gas Co., Portland, Ore.

Transmission line installed in 1930 through fairly corrosive soils without coating protection had a total loss of over 30 percent of total length. Replacements lengths were installed with coatings to reduce amount of protection required from the cathodic protection system used on the pipe after it was repaired.

Resistance of Aluminum Alloys to Underground Corrosion, by D. O. Sprowls and M. E. Carlisle, Jr., Aluminum Company of America, New Kensington, Pa.

Summarizes field test data and service experience on aluminum used in underground applications. Discusses effect of variations in soil composition and the relative performance of different alloys. Considers cathodic protection, protective coatings, stray currents and galvanic effects. Experince with several aluminum pipe lines is given.

High Purity Water

Thursday, March 17, 2–4:30 pm

Chairman B. G. Schultz, Westinghouse Electric Co., Pittsburgh, Pa.

Co-Chairman W. K. Boyd, Battelle Memorial Institute, Columbus, Ohio.

Aluminum Alloys for Handling High Temperature Water, by M. H. Brown, R. H. Brown and W. W. Binger, Aluminum Company of America, New Kensington, Pa.

Aluminum alloys with good corrosion resistance to high temperature water in static tests were obtained by additions of alloying elements such as iron, nickel, cobalt, rhodium or copper. Minor elements play an important role in the aluminum-nickel-iron alloys and should be controlled to obtain best corrosion performance. Aluminum powder metallurgy products containing additions of iron and nickel also appear promising for corrosion resistance and have advantage of higher strength at elevated temperatures than wrought alloys of comparable composition.

Corrosion of Carbon and Low Alloy Steels in Out-of-Pile Boiling Water Reactor Environment, by D. C. Vreeland, U. S. Steel Corp., Monroeville, Pa., G. G. Gaul and W. L. Pearl, General Electric Co., Vallecitos Atomic Laboratory, San Jose, Cal.

Gives results of corrosion tests on carbon and low alloy steels in a dynamic test loop simulating various environments in nuclear boiling water reactor system. Quantitative data and metallographic and visual observations of specimens tested in saturated steam, saturated water and a steam-water mixture at 545 F and 1000 psi are given. Also describes test facilities and operating procedures.

Lists total corrosion and corrosion product to system. Reviews special corrosion studies on carbon steel in water with variable hydrogen and oxygen contents. Outlines future work to prove feasibility of carbon and low alloy steels for these reactor systems.

Use of Neutron Activated Specimens for Study of Corrosion Product Release Rates, by G. P. Simon, Westinghouse Electric Corp., Bettis Atomic Power Laboratory, Pittsburgh, Pa.

Describes a once-through system for quantitative evaluation of transient corrosion product release rates of various materials of construction. System was designed to operate at fluid velocity of about 4.0 fps and 500 F in the test section. Runs have been conducted for periods to 750 hours. Presents operating data for runs made with 304 stainless steel and Inconel in contact with water at pH 10.0 to 10.5 using LiCH for pH control. Observed radiochemical data is given and used to calculate corrosion product release rates for the materials.

Inhibitors

Session Two
Thursday, March 17, 2–4:30 pm

Passivation of Metals and Alloys by Oxidizing Inhibitors, by A. C. Makrides, Union Carbide Metals Co., Niagara Falls, N.Y.

Describes metal and alloy passivation by oxidizing inhibitors in terms of relevant electrochemical parameters subject to independent measurement. Most important of these are primary passive potential and corresponding critical current density for metal to be protected. For the inhibitor, the reversible potential, exchange current density and Tafel slope are important.

Study of passivation of several metals and alloys by ferric ion in sulfuric acid solutions gave a direct quantitative correlation between these parameters. Systems studied showed that adsorption of ferric ion, if any, played no role in mechanism of inhibition.

Inhibition of Corrosion of Commercial Aluminum in Alkaline Solutions, by J. Sundararajan and T. L. Rama Char, Indian Institute of Science, Bangalore, India.

Corrosion rates for aluminum (4 percent manganese and 3 percent ion) were determined in sodium hydroxide solutions under different conditions. Inhibitor efficiencies were calculated for agar-agar, gum-acacia, dextrin, gelatin and glue. Efficiency decreased from 90 to 60 percent in the order listed. Studies of cathodic and anodic polarization show that metal dissolution is electrochemical in character. Corrosion appears to be under mixed control with predominance of action of dextrin inhibitor on anodic areas of the metallic surface.

Inhibitors —

Inhibition of Corrosion of Hypereutectic Aluminum-Silicon Automobile Engine, by H. Lee Craig, Jr., and Patrick H. Woods, Reynolds Metals Co., Richmond, Va.

Present corrosion test data on hypereutectic aluminum-silicon alloys under conditions related to automobile engine cooling systems. Galvanic coupling to copper in the systems gave greatest corrosion of the effects studied. Corrosion of the alloys was reduced when they were galvanically coupled to copper. Results were based on inorganic and organic inhibitors added to single and double phase antifreeze solutions.

Marine Corrosion

Friday, March 18, 9–11:30 am

Chairman R. O. Norris, Cities Service Research and Development Co., Lake Charles, La.

A Novel Cathodic Protection System for Tanker Ships, by W. L. Miller, U. S. Naval Material Laboratory, Brooklyn, N. Y.

Describes an experimental magnesium anode-bottom coating combination system designed by author for installation on an MSTS T2 oiler and the USNS Mascoma. Objects were to simplify installation and reduce long range costs by having all anodes at tank bottom and to prevent bottom pitting while not in ballast and to eliminate sparking hazards from falling magnesium. After one year's use in 10 tanks, typical advantages were observed. Little wear of the anodes indicated at least a 10-year life for the installation. Information was obtained for planning long service combination systems.

Cathodic Protection of Offshore Platforms, by Wayne A. Johnson, Corrosion Rectifying Co., Houston, Texas

Explains principle of protecting offshore platforms, docks and wharves. Discusses tests used to determine corrosiveness of water and method of determining criteria of protection. Different types of protection systems are explained. Outlines various methods of installing anodes.

Magnesium Anode Designs for Effective Non-Hazardous Cathodic Protection of Ballast Tanks, by Richard D. Taylor and George W. Kurr, American Smelting and Refining Co.

Discusses designs of magnesium anodes, mounts and fastenings for effective, economical and non-hazardous cathodic protection of ballast tanks of tankers, ore carriers, etc. Covers such factors as size of cat in cores, bonding of cores, dielectric coatings on cores, mounting and fastening techniques with emphasis on non-hazardous operation. Data is given on results of vibration tests conducted on various anode designs and mounts.

An Investigation of the Corrosion Rate of Mild Steel in San Diego Harbor, by M. H. Peterson and L. J. Waldron, U. S. Naval Research Laboratory, Washington 25, D. C.

Basic corrosion rate at San Diego has been determined by exposure of mild steel panels for 6, 12 and 18 months. Corrosion rate determined by weight loss and degree of pitting determined by pit depth measurements were measured for unprotected panels and for three different levels of cathodic protection. Basic corrosion rate for unprotected panels over one-year exposure was 25.8 mdd and greatest pit depth exceeded 60 thousandths of an inch. Fully protected panels had almost no corrosion; partially protected panels had a corrosion rate of 8.3 mdd. Greatest pit depth on partially protected panels was only 9 mils.

Details on Technical Committee Meetings To Be in February Issue

Details of Technical Committee meetings to be held at Dallas during the 1960 NACE Annual Conference will be published in the Technical Committee Activities Section of the February issue of CORROSION. Persons interested in these meetings are urged to get the necessary information from the February issue.

1960 Corrosion Show Exhibitors

Arranged by Booth Numbers

Booth No.

1 & 2—John-Manville Sales Corp.
3—Tinker & Rasor
4 & 5—Plicoflex, Inc.
6 & 7—Chicago Bridge & Iron Company
8—Stewart R. Browne Mfg. Co., Inc.
9—Tubular Lining Corp.
10—Hills-McCanna Company
11—Pipe Linings, Inc.
12—Agra Engineering Company
13—Fansteel Metallurgical Corp.
14—T. D. Williamson, Inc.
15—The Tapecoat Company
16—The D. E. Stearns Company
17—R. H. Maloney Company
18—Pittsburgh Corning Corporation
19—Lincoln Engineering Company
20—R. C. Foltz Company
21—Rockcote Paint Company
22—Corrosion Rectifying Co.
23—Otis Engineering Corporation
24, 25, 26—Resistoflex Corp.
27—Kraloy Plastic Pipe Company
28—Centriline Corporation
29 & 30—The Pfaudler Company
31—Cosasco Div., Grant Oil Tool
32 & 33—Amercoat Corporation
34 & 35—Coast Paint & Lacquer Co.
36 & 37—The Dow Chemical Co.

Booth No.

38 & 39—Shell Chemical Corp.
40 & 41—Aluminum Co. of America
42—Royston Laboratories, Inc.
43 & 44—The Duriron Company, Inc.
45 & 46—The U. S. Stoneware Co.
47—Harco Corporation
48—Phelps Dodge Copper Products Co.
49 & 50—Armco Steel Corp.
51—Orchard Paper Company
52 & 53—Shell Oil Company
54—Truscon Laboratories
55—Metal-Cladding, Inc.
56—The Dia-Log Company
57—M. J. Crose Mfg. Co., Inc.
58—Hercules Powder Company
59—Nicolet Industries, Inc.
60—Minnesota Mining & Mfg. Co., Tape Div.
61 & 62—The Kendall Co., Polyken Sales Div.
63—Cameron Iron Works, Inc.
64 & 65—Brance-Krachy Co., Inc.
66—Tejas Plastic Materials Supply Co.
67—Visco Products Company, Inc.
68—Central Plastics Company
69—Chas. Pfizer & Co., Inc.
70 & 71—Owens Corning Fiberglass Corp.
72 & 73—Crane Company
74—The DeVilbiss Company
75—Standard Magnesium Corporation
76 & 77—The Glidden Company.

Booth No.

78—American Hot Dip Galvanizers Assoc.
79 & 80—American Smelting & Refining Co.
81 & 82—Koppers Co., Inc.
83 & 84—Carboline Company
86—The Carpenter Steel Co.
87 & 88—Pittsburgh Coke & Chemical Co.
89—National Carbon Co.
90—John L. Doré Co.
91 & 92—Dresser Manufacturing Div.
93—Clemtex, Ltd.
94—Fibercast Company
95—Rio Engineering Co.
96—Burndy Corporation
97—Radio Receptor Co., Inc.
98—Reilly Tar & Chemical Corp.
99 & 100—The International Nickel Co., Inc.
101 & 102—Enjay Company
103 & 104—Cathodic Protection Service
105—Good-All Electric Mfg. Co.
106 & 107—Metallizing Engineering Co., Inc.
108 & 109—Clementina, Ltd.
110—Gulf States Asphalt Co., Inc.
111—Sentinel Chemicals, Inc.
112—The Garlock Packing Co.
113—A. M. Byers Co.
114—Crucible Steel of America
115—Socony Paint Products Co.
116—Wheelabrator Corporation
117 & Outside Booth—Black, Sivalls & Bryson
118—Victaulic Company of America
120—Heil Process Equip. Co.
121—Republic Steel Corporation

Partial List of Products at 1960 Corrosion Show

Investigate These Scheduled NACE Corrosion Shows

If you make or sell corrosion control materials, license or install corrosion control systems or offer any engineering service connected with corrosion you should consider the advantages of exhibiting at a Corrosion Show.

Complete advance information about NACE's 1961 Corrosion Show to be held at Buffalo, N.Y., March 13-17 will be available early in the Spring. If you are interested write to R. W. Huff, Jr., Exhibits Manager, NACE, 1061 M & M Bldg., Houston 2, Texas.

Other Corrosion Shows are scheduled for 1962 at the Kansas City Municipal Auditorium and in 1963 at Atlantic City, N.J. If you are not on the mailing list already to get advance notice about these events write to Mr. Huff.

Authors of Technical Papers, 16th Annual NACE Conference

Agricola

Alexander

Allen

Annand

Anthony

Atkinson

Berg

Binger

Boyd

Bradstreet

M. H. Brown

R. H. Brown

Bruns

Buck

Buckley

Carlisle

Chatten

Cogshall

Colvin

Cook

Copson

Couper

Craig

Derr

Dial

Dillon

Doremus

Dravnieks

Ellis

Erben

16th Annual Conference
BIOGRAPHIES

K. R. AGRICOLA is metals group engineer with the Martin Company, Denver, Colo. His activities are on advanced materials evaluation and application. He has a BS from Michigan College of Mining and Technology and an MS in metallurgical engineering from Pennsylvania State University. Previously he was associated with Wright Air Development Center as project engineer on high temperature alloys and reactor materials.

A. L. ALEXANDER is affiliated with the chemistry branch of the U. S. Naval Research Laboratory. Active in NACE conferences, short courses and technical symposia, he is also a member of ACS, ASTM and Federation of Paint and Varnish Production Clubs. He has a PhD from the University of North Carolina.

J. R. ALLEN is associated with the engineering service division of E. I. du Pont de Nemours & Co., Inc., Wilmington, Del. He has a BS in ceramic engineering from Georgia Institute of Technology. His work as an engineering materials consultant is concerned with protective coatings and thermal insulation. He has been a member of du Pont's Protective Coatings Committee since its organization.

ROBERT R. ANNAND, research chemist with Texas Research Associates, Austin, Texas, has a BS in chemistry from the University of Texas. His work is in synthesis and testing of organic compounds for corrosion inhibitors.

D. R. ANTHONY, a chemical engineer in the corrosion group of Atlantic Refining Company's Crude Oil Production Division, has been with the company since 1954. He has a BS and MS in chemical engineering from the University of Michigan.

H. E. ATKINSON is materials consultant for the engineering department at E. I. du Pont de Nemours & Co., Inc. For the past six years he has specialized in the uses of plastics as materials of construction. He has a BS in mechanical engineering from Virginia Polytechnic Institute. He is a member of ASTM and ASA.

R. M. BERG is staff manager of the development department at Union Carbide Chemicals Co., South Charleston, W. Va., where he has been employed since 1940. He is a member of ASTM and the American Society for Quality Control and has a BS in electrical engineering from the University of Wisconsin.

W. W. BINGER, chief of the chemical metallurgy division of the Alcoa Research Laboratories, New Kensington, Pa., has been with Alcoa since 1943. His principal activity has been in development of aluminum alloys for chemical industry applications. He was the 1959 chairman of the NACE Northeast Region and has a BS in chemical engineering from the University of Wisconsin.

WALTER K. BOYD is assistant chief of the Corrosion Research Division at Battelle Memorial Institute, Columbus, Ohio. An NACE member, he has contributed to development of low and high temperature corrosion resistant stainless steel alloys and lately has been working on corrosion resistant uranium and zirconium materials.

S. W. BRADSTREET, JR., is supervisor of inorganic technology at the Armour Research Foundation, Chicago, Ill. He is co-inventor of solution ceramics, slurry ceramics and flame ceramic processes. He has a BS from Cornell University and an MS from California Institute of Technology.

M. H. BROWN has been employed in the Chemical Metallurgy Division of the Alcoa Research Laboratories, New Kensington, Pa., since 1951. His work is primarily devoted to applications of aluminum alloys in the chemical industries. He has a PhD in chemical engineering from Iowa State College.

R. H. BROWN, 1950 winner of the NACE Whitney Award for outstanding contributions to the science of corrosion, joined the Alcoa Research Laboratories in 1931. He has a BS in chemical engineering from Drexel Institute of Technology and an MS from Massachusetts Institute of Technology. His activities have been devoted to the study of corrosion and metallurgical problems. A pioneer in establishing the cathodic protection theory, he has written about 50 articles and discussions for technical journals. Also he has developed electrochemical methods used to study diffusion of metals and the internal structure of alloys.

FRANK J. BRUNS is associated with the Sinclair Research Laboratories, Harvey, Ill. He has a BS in metallurgical engineering from the University of Illinois and a MBA from the University of Chicago. Formerly he was employed by Standard Oil of Indiana.

W. ROGER BUCK, III, is a senior research chemist at the Virginia Institute for Scientific Research, Richmond, Va. He has a BS in chemistry from the University of Richmond and an MS in physical chemistry from Duke University. He is a member of NACE, ACS and the Electrochemical Society.

DONALD H. BUCKLEY is associated with the National Aeronautics Space Administration as an aeronautical lubrication research engineer. He has a BS from John Carroll University and is engaged in high temperature lubrication research. He is a member of the American Society of Lubrication Engineers and ACS.

M. E. CARLISLE, JR., engineer in the sales development division of the Aluminum Company of America, is a specialist on the use of aluminum in petroleum industry operations. He has a BS in industrial management from Carnegie Institute of Technology.

FRANK L. CHATTEN is system engineer in communications and signals for the Pennsylvania Railroad and is in charge of construction and maintenance of those facilities. He has a BS in electrical engineering from Rutgers University and is a member of the Association of American Railroads and AIEE.

JAMES H. COGSHALL is sales manager of Pensalt Chemicals Corporation's Corrosion Engineering Products Department, Natrona, Pa. A chemical engineering graduate of the University of Pennsylvania, he has been engaged in corrosion engineering for 13 years and has been active in NACE for 10 years. He is author of several papers on corrosion and has been symposium chairman for NACE meetings on protective coatings.

FAIR COLVIN, JR., is regional corrosion engineer for the Atlantic Refining Company's West Texas-New Mexico region. A member of NACE and AIME, he has a BS in chemical engineering from Texas A & M College.

E. H. COOK, JR., is research engineer in the chemical metallurgy division at the Alcoa Research Laboratories, New Kensington, Pa. His work is primarily in fundamental studies of corrosion mechanisms and development of aluminum alloys for the chemical industry. He is a member of NACE and has a PhD in chemistry from Pennsylvania State University.

HARRY R. COPSON is head of the Corrosion Section, Research Laboratory, International Nickel Co.. Inc., Bayonne, N. J. Active in NACE work and author of several articles on corrosion, he has a BS from the University of Massachusetts and a PhD in physical chemistry from Yale.

A. S. COUPER is assistant project engineer of the corrosion section, Materials Division with Standard Oil Company of Indiana. He has an MS from Montana State College and has been with Standard since 1953. He has worked on pilot plant developments on petrochemicals and general research on corrosion.

H. LEE CRAIG, JR., is research supervisor of the chemical metallurgy section, Metallurgical Research Laboratories, Reynolds Metals Company. He has a BA, MS and PhD in chemistry from the University of Pennsylvania and is a member of NACE, ACS, ASM and ASTM.

PAUL F. DERR is technical assistant to the director of the inorganic research and development department of the Food Machinery and Chemical Corporation. His work has been in rocket fuels. He has a PhD from Duke University and is a member of ACS, American Rocket Society, the Electrochemical Society and the Chemical Industry Association.

ROY E. DIAL is supervising engineer in the engineering research branch of Carborundum's Central Research and Development Laboratories. Formerly he was a research chemist for the Alcoa Research Laboratories and General Aniline and Film Corporation. He has a BS and PhD from the University of Illinois.

CHARLES P. DILLON has been group leader of the Corrosion and Metallurgical Group at the Texas City plant of Union Carbide Chemicals Corporation since 1950. Author of several articles on chemical process, cooling water and tanker corrosion, he is active in NACE and also is a member of ACS and ASM.

E. P. DOREMUS is president of Cathodic Protection Service, Houston, Texas. He has a BS in chemical engineering from Southwest Louisiana Institute and an MS from Louisiana State University. Formerly with Shell Oil Company, he is a member of NACE and also vice president of Grebe & Doremus Process Company.

ANDREW DRAVNIEKS, head of the Corrosion Section, Material Division, Engineering Research Department, Standard Oil Company of Indiana, attended the University of Latvia and Marburg University, Germany. He has a PhD from the Illinois Institute of Technology. He has done work in paint technology, polarography, surface chemistry and in the kinetics of corrosion processes.

O. B. ELLIS is senior research engineer with Armco Steel Corporation, where he has been employed since 1932. He has a BS in chemistry and an MS in physics from the University of Louisville.

ALFRED R. ERBEN, an NACE member. is a chemist in the corrosion department of the Chemical Test Section, Sun Oil Company, Production Laboratory, Richardson, Texas. He has a BS and MA in chemistry from Southwest Texas State College.

OTTO H. FENNER is associated with Monsanto Chemical Company in St. Louis. He helped organize the NACE Greater St. Louis Section, served as its chairman and has been an officer on several NACE Technical Committees. He has a BA in organic chemistry from Washington University.

FREDERICK W. FINK has specialized in corrosion studies in non-ferrous metals and stainless steels since joining the staff of Battelle Memorial Institute in 1938. In NACE, he has been chairman of technical committees and symposium chairman at national conferences. He has a BS from Cornell University and an MS from the University of Cambridge (England) and is a member of NACE, ASM, AIME and the Electrochemical Society.

M. D. FOLZENLOGEN is a chemical engineer with the Atlantic Refining Co., Dallas, Texas. He has a BS in cheimcal engineering from Texas A & M College and has been a member of the company's corrosion group since 1951.

B. W. FORGESON, an NACE member, is affiliated with the Naval Research Laboratory. Since 1953 he has been in charge of tropical exposure and laboratory facilities in the Panama Canal Zone.

JOSEPH S. FRINK is an engineer with the Houston Corp., St. Petersburg, Fla. An NACE member active in the Southeast Region, he has written papers in the gas industry and corrosion engineering fields.

D. W. GATES is associated with the Army Ballistic Missile Agency, Huntsville, Ala. Formerly he was assistant professor in the ceramic department at Clemson College. He has been co-author of several articles on exploration geophysics and ceramic testing of porcelain enamels and clay materials.

LEO E. GATZEK is head of the Materials Application Section, Engineering Design Department at the Space Technology Laboratories, Los Angeles, Cal. Formerly he was with Bendix Aircraft Corporation. He has a BS from the University of Chicago and is a member of American Welding Society, ASM and AIME.

G. G. GAUL is a metallurgist for the chemical engineering unit at General Electric's Vallecitos Atomic Laboratory. Formerly he was associated with Cutler Hammer, Inc. He is a member of AIME and ASM.

W. D. GREATHOUSE is supervisor of the Materials Section, Production Research Division, Continental Oil Co., Ponca City, Okla. He is co-author of several papers on petroleum production corrosion problems, has a BS in chemical engineering from Texas Technological College and is a member of NACE and AIME.

NORMAN HACKERMAN is head of the University of Texas Chemistry Department. Active in NACE since 1946, he organized and conducted an NACE short course on corrosion at the University of Texas in 1949. He was technical program committee chairman for the 1951 NACE Conference and is currently chairman of the NACE Education Committee. He has published several articles on corrosion studies and is a member of NACE, ACS, the Electrochemical Society, AAAS and the Gordon Research Conference on Corrosion.

ROBERT L. HADLEY is engineering manager of General Electric's Metallurgical and Ceramic Development Group, Major Appliance Laboratory, Louisville, Ky. He has a BS from Purdue University and an MS and PhD from Carnegie Institute of Technology.

J. E. HALKIAS is senior engineering chemist with Convair Fort Worth, a division of General Dynamics Corp. Currently his department is working on corrosion studies of aircraft structural materials. He has a BS in chemical engineering from Texas A & M College.

JOHN O. HARRIS has been on staff of Kansas State University since 1941. He is professor of bacteriology and bacterial physiologist at the Kansas Agricultural Experiment Station. An NACE member, he has a BS and PhD from Kansas State and an MS from the University of Hawaii. His research work has included hydrocarbon oxidation, asphalt road deterioration and pipeline coating breakdown.

Authors of Technical Papers, 16th Annual NACE Conference

Fenner	Fink	Folzenlogen	Forgeson	Frink	Gates
Gatzek	Gaul	Greathouse	Hackerman	Hadley	Halkias
Harris	Helms	Hopkinson	Horst	Howells	Hudgins
Hurd	Huscher	Robert Johnson	Wayne Johnson	Kennedy	Kerst
Kinsley	Krupka	Ladley	Landers	Landis	Larrabee

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BIOGRAPHIES

(Continued From Page 47)

F. PARKER HELMS, an NACE member, is head of the paint and insulation section at Union Carbide Chemical Co., Texas City, Texas. He has a BS in chemical engineering from the University of Arkansas and is active in NACE technical committee work.

B. E. HOPKINSON is a research chemist in the Corrosion Section of the International Nickel Co., Inc., Bayonne, N.J. He has a BS in chemistry from London University and is a member of the Electrochemical Society and the Faraday Society.

R. L. HORST, JR., is affiliated with the sales development division of the Aluminum Company of America, New Kensington, Pa. His work is on aluminum applications in the chemical and process industries. An NACE member and a graduate of Columbia University, he has published several articles on aluminum and cathodic protection by aluminum and magnesium anodes.

E. HOWELLS is test engineer for water and liquid metal corrosion studies at Babcock & Wilcox Company Research and Development Center, Alliance, Ohio. He has a BS in chemistry from Columbia University and formerly was associated with Johns-Manville Research and Development Center.

C. M. HUDGINS, JR., is a research chemist in the Materials Section of the Production Research Division, Continental Oil Co., Ponca City, Okla. He is concerned with corrosion and special physical chemistry problems encountered in production of oil. He has a BS and MS from Texas A & M College and a PhD from Louisiana State University.

RAY M. HURD is director of chemical research at Texas Research Associates and Defense Research Laboratory, University of Texas, Austin. Formerly he was research chemist with the Atlantic Refining Co., Dallas. He has a BA from the University of Oklahoma and a BS and PhD in chemistry from the University of Texas.

JOSEPH L. HUSCHER has been with American Agile Corporation since 1941, working originally on development of special metallic welding electrodes and procedures. His work also has involved evaluation of plastic materials and their corrosion resistance. An NACE member, he has a BS in chemistry from the University of Caen (France) and a BS in chemical engineering from Fenn College.

ROBERT L. JOHNSON is head of the Lubrication Section at the National Aeronautical Space Administration's Lewis Research Center. He has a BS in mechanical engineering from Montana State College.

WAYNE A. JOHNSON is president of Corrosion Rectifying Company, Houston, Texas and is author of several technical articles on corrosion and cathodic protection. He is a member of NACE and a graduate of Texas A & I College.

FRANK M. KENNEDY, JR., is affiliated with Palladium Mastic Corporation of America, Rutherford, N. J. His work is in the manufacture and application of mastics and other types of coatings for corrosion control. He has been an NACE member since 1952.

HERMAN KERST is senior research leader for Dearborn Chemical Company and is engaged in development work on corrosion control and scale in cooling waters. An NACE member, he has a BS and MS from the University of Wisconsin and is member also of ACS, AAAS and the Electrochemical Society.

E. J. KINSLEY, a chemist for the past 10 years with Bell Aircraft Corporation, is active in the development of compatible materials and preprocessing technique for use in 90 percent hydrogen peroxide service. He has a BS in chemistry from Canisius College.

RAYMOND M. KRUPKA is a research engineer with the Chicago Midway Laboratories, University of Chicago. He has a BS and MS in mechanical engineering from the Illinois Institute of Technology and is a member of ASME.

GEORGE W. KURR is manager of the Cathodic Protection Department of American Smelting and Refining Co., Federated Metals Division, New York, N. Y. His experience has been in design of magnesium anodes and systems for cathodic protection of ballast tanks of tankers and ore carriers. An NACE member since 1954, he has a BS in metallurgical engineering from the University of Kentucky.

R. STANLEY LADLEY is a corrosion engineer with Phillips Petroleum Co., Bartlesville, Okla. A member of NACE, he has a BS in metallurgical engineering from the University of Illinois.

JAMES E. LANDERS is associated with Continental Oil Company's Development and Research Department, Ponca City, Okla. An NACE member since 1952, he attended Southern Methodist University.

N. J. LANDIS has been a materials and corrosion specialist in the General Engineering Division of Standard Oil Company of Ohio, Cleveland, Ohio, since 1955. He is an NACE member and has a BS in chemical engineering from Cast Institute of Technology.

C. P. LARRABEE, former chairman of the NACE Technical Practices Committee, has spent more than 20 years in charge of corrosion work in the Research and Development Laboratory of U. S. Steel Corp., Monroeville, Pa. He has several articles published on corrosion reactions.

ROBERT A. LEGAULT is a research chemist with the Sun Oil Company, Richardson, Texas. An NACE member, he has a PhD in physical chemistry from the University of Texas.

HENRY LEIDHEISER, JR., is director of research at the Virginia Institute for Scientific Research, Richmond, Va. He has a PhD in physical chemistry from the University of Virginia. His fields of interest are surface properties of metals, electroplating and corrosion.

ALEXEI W. LOGINOW is associated with the Applied Research Laboratory, U. S. Steel Corp., Monroeville, Pa. Member of NACE and ASM, he has a BS in metallurgical engineering from Carnegie Institute of Technology. His work is in stress corrosion research of stainless, alloy and carbon steels.

RADO LONCARIC is chemical engineer with Atlantic Refining Company, Dallas, Texas. He has been with the company's corrosion group in the Crude Oil Production Department for three years. He has a BS from the University of Ljubljana, Yugoslavia and an MS from Technishe Hochshule in Austria.

AUSTIN K. LONG is manager of maintenance field service with the Glidden Company. His duties include formulation, testing, application, inspection and specification writing for industrial maintenance coatings. An NACE member, he has a BS and MS in chemical engineering from Lehigh University and has been in maintenance coatings work for 12 years.

C. M. LOUCKS is technical director of Materials and Methods, Inc. Formerly he was associated with Dow Chemical Company and was a chemistry professor at the University of Tulsa. He is secretary of NACE Technical Committee T-8A and has a BS from St. Lawrence University, an MS from the University of Illinois and a PhD from New York University.

R. McFARLAND, secretary and technical director of Hills-McCanna Co., has been engaged in design and application of pumps, valves and allied equipment for over 20 years. An NACE member, he has been chairman of NACE Technical Committee T-6A and also is a member of AIChE, ACS and ASM. He is a graduate of Armour Institute of Technology's school of chemical engineering.

R. L. McGLASSON is a metallurgist in the Materials Section of Production Research of Continental Oil Company. His work deals with corrosion metallurgy. He has a BS in physics and mathematics from Northwestern State Collage (Okla.). Formerly he was employed by Boeing Airplane Company.

T. A. McNARY is an associate metallurgist with Babcock & Wilcox Research Center. His work is primarily in corrosion of heat exchanger materials in aqueous solutions. He has a BS in metallurgy from Grove City College.

T. J. MAITLAND is electrolysis and protection engineer with the Long Line Department of American Telephone and Telegraph Co., New York, N. Y. A member of NACE since 1944, he is chairman of the NACE Technical Practices Committee and officer of three technical committees. His professional career has been devoted to corrosion control, cable construction and maintenance methods of long distance telephone cables.

A. C. MAKRIDES is research chemist at the Metals Research Laboratories of Union Carbide Metals Company, Niagara Falls, N. Y. He is a member of ACS, Faraday Society and the Electrochemical Society.

GLEN A. MARSH is affiliated with Pure Oil Research Center, Crystal Lake, Ill. He has been doing corrosion research for the company since 1948. He has a BS in chemistry from Illinois Institute of Technology and an MS in chemistry from Northwestern University.

CECIL R. MASON, JR., assistant research engineer at the Georgia Tech Engineering Experiment Station, directs research on development of high temperature refractory materials, especially fused silica. He has a BS in ceramic engineering from Georgia Institute of Technology.

J. F. MASON, JR., has been a member of the Corrosion Engineering Section of the International Nickel Co., Inc., for 18 years. He has a BS in chemistry from Manhattan College and has written several technical papers on metallic corrosion.

THOMAS P. MAY is manager of Inco's Harbor Island Testing Station. Formerly he was head of the corrosion section of the Chemistry Division, U. S. Naval Research Laboratory. An NACE member since 1947, he has a BS, MS and PhD from the Catholic University of America.

ROBERT D. MERRICK is head of the Corrosion Research Group at Esso Research and Engineering Co., Linden, N. J. He is an NACE member and has a BS in metallurgical engineering from Purdue University and an MS in chemical engineering from Newark College of Engineering.

HARVEY S. MILLER is president and general manager of New England Hard Facing Co., Inc. An industrial engineering graduate of Northeastern University, he is an NACE member and was 1958 chairman of the NACE Northeast Region Conference.

W. L. MILLER is head of the metal chemistry section at the Naval Material Laboratory, Brooklyn, N. Y. He has been active in ship corrosion work, has a BS in chemistry from Columbia University and is a member of NACE, ACS and RESA.

MICHAEL L. MONACK is supervisor of the Engineering Materials Technology Group at E. I. du Pont de Nemours & Co., Inc., Wilmington, Del. He has been chairman of du Pont's Protective Coatings Committee. He is a member of NACE and has a BS in metallurgy from Pennsylvania State University.

NICK MONSOUR is a senior engineer in the inspection and standards section of the Engineering and Construction Department at Polymer Corporation, Ltd., Canada. He is a mechanical engineering graduate of the University of Toronto.

KENNETH L. MOORE is a corrosion engineer with Tidewater Oil Co., Delaware City. Del. He joined this company in 1957 after three years of process design and corrosion work with Atlantic Refining Company. An NACE member, he has a BS in chemical engineering and metallurgical engineering from the University of Michigan.

J. J. MORAN is a metallurgist in the Corrosion Engineering Section, Development and Research Division of International Nickel Co., Inc., New York, N. Y., where his work is on corrosion of metals at high temperatures. A member of NACE, ASM, and ASTM, he has a BS in metallurgy from Massachusetts Institute of Technology. He joined International Nickel in 1951.

FRANK B. MURPHY is associated with the sales division of the Aluminum Company of America, where he has been active in corrosion work and development of aluminum applications in the chemical and petroleum industries. A member of NACE, AIChE and ACS, he has a BS in chemical engineering from Grove City College.

E. E. NELSON is a corrosion engineer at Socony Mobil Oil Company's Brooklyn Technical Service Laboratory. Formerly he was with the Naval Research Laboratory for 11 years. He has been an NACE member since 1954.

WALTER P. NOSER, senior corrosion engineer with Humble Pipe Line Company, Houston, Texas, has been active in corrosion control work since 1941. He helped in the early organization of NACE and was the first chairman of the NACE Houston Section. He has a BS in electrical engineering from the University of Texas.

J. T. PARMENTIER is a materials engineer for the Martin Company's Activation Division. His work has included development of a system used on the Titan missile for galvanic corrosion protection of magnesium-thorium alloys. He is a member of ASM.

BURTON S. PAYNE, JR., is manager of new products research with the Pfaudler Division of Pfaudler-Permutit, Inc., Rochester, N. Y. He has a BS in metallurgical engineering from Rensselaer Polytechnic Institute.

W. L. PEARL is manager of the Chemical Engineering Unit at General Electric's Vallecitos Atomic Laboratory, San Jose, Cal. He has been with GE's commercial atomic power interests since 1945 and has a BS in chemical engineering from the University of Washington and an MS and PhD from the Institute of Paper Chemistry. He is a member of NACE, ACS, AIChE and ANS.

Authors of Technical Papers, 16th Annual NACE Conference

Legault

Leidheiser

Loginow

Loncaric

Long

Loucks

McFarland

McGlasson

McNary

Maitland

Makrides

Marsh

C. R. Mason

J. F. Mason

May

Merrick

H. S. Miller

W. L. Miller

Monack

Monsour

Moore

Moran

Murphy

Nelson

Noser

Parmentier

Payne

Pearl

Peterson

Phelps

16th Annual Conference
BIOGRAPHIES

(Continued From Page 50)

MILLER H. PETERSON is a member of the Marine Corrosion Section, Physical Metallurgy Branch in the Metallurgy Division of the U. S. Naval Research Laboratory, Washington, D. C., where he has been part of a group working on cathodic protection of naval vessels. He has a BS in chemistry from Clemson College and an MA in analytical chemistry from the University of North Carolina.

E. H. PHELPS is assistant division chief in the Chemical-Metallurgy Division, Applied Research Laboratory, U. S. Steel Corp., Monroeville, Pa. A member of NACE and the Electrochemical Society, he has a BS from Clarkson College of Technology and an MS and PhD from Case Institute of Technology.

F. J. PLOEDERL, a business partner in Wisconsin Protective Coating Co., Green Bay, Wis., has been in corrosion control work over 20 years. Active in NACE work, he will be chairman of the protective coatings symposium at NACE's 1961 Conference in Buffalo, N. Y. He has presented several papers on corrosion and has participated in short courses on corrosion at the University of Wisconsin and Case Institute of Technology.

DAVID KENNETH PRIEST is manager of the applied research department, Pfaudler Division, Pfaudler-Permutit, Inc., Rochester, N. Y. He has a BS, MS and PhD from Ohio State University, where he was a research associate for two years.

P. R. PUCKORIUS is a staff engineer in the water stabilization department of Nalco Chemical Company. His principal work is on cooling water treatments. A member of NACE, ACS and AWWA, he has a BS in chemistry from North Central (Illinois) College and has co-authored several papers on corrosion treatments and evaluation in cooling water systems.

CHARLES W. RALEIGH is a chemical engineer in the Special Projects Laboratory at Food Machinery and Chemical Corp., Buffalo, N. Y. His work is in liquid propellants for missiles. He has a BS in chemical engineering from Northeastern University.

T. L. RAMA CHAR is assistant professor in physical chemistry at the Indian Institute of Science, Bangalore, India. He directs electrochemical research in electrodeposition and corrosion of metals and has published over 80 technical papers. He is a member of the Electrochemical Society, Institute of Physics, Royal Institute of Chemistry, Institution of Metallurgists and Indian Institute of Chemical Engineers.

VICTOR G. REILING is president of Modern Industrial Plastics, Inc., Dayton, Ohio. He has a BS in electrical engineering from the University of Dayton and a MS in physics from the University of Notre Dame. He is a member of the Society of Plastic Engineers.

MAX S. ROBINSON has been employed in rocket propellants work with the Martin-Denver Company since 1958. He has a BS in chemical engineering from the University of Utah.

GILSON H. ROHRBACK has been associated with Magna Products since 1952 and formerly was with the California Research Corporation. He has a PhD in chemistry from the University of Washington.

DAVID ROLLER is corporate project administrator at Magna Products, Inc. A member of NACE, he is chairman of Technical Committee T-5B. Before joining Magna Products recently, he was senior project engineer at Wright Air Development Center in Ohio.

HENRY T. RUDOLF is president of Atlantic Coatings, Co., Inc., Jacksonville, Fla. An NACE member in the Jacksonville Section, he has several technical articles published on corrosion and surface preparation by blasting. He has two engineering degrees from Lafayette College.

W. J. RYZNER is a senior chemist in the Physical Chemistry Department of Nalco Chemical Company. Currently he is engaged in research and development of corrosion and scale inhibitors for cooling water systems. He has a BS in chemistry from St. Mary's College and is a member of NACE.

EDWARD SCHASCHL is affiliated with Pure Oil Research Center, Crystal Lake, Ill., where he is working on research problems in metallurgy and corrosion. He has a BS in chemical engineering from Illinois Institute of Technology.

N. T. SHIDELER is manager of protective coatings research for Pittsburgh Coke & Chemical

Company. Most of his professional career has been in the field of coal tar coatings. He has a BA in chemistry from Indiana University.

GEORGE P. SIMON is associated with the chemistry development section of the Bettis Atomic Power Laboratory, Pittsburgh, Pa. For the past five years he has been doing corrosion studies of construction materials and developing useful techniques in evaluating ion-exchange materials.

E. N. SKINNER, JR., is affiliated with International Nickel Co., Inc., where his activities have been in alloys selection for high temperature service. He is an NACE member and has a PhD in metallurgy from Yale University.

HAROLD J. SMITH since 1955 has been with General Electric's Metallurgy and Ceramics Laboratory, Major Appliance and TV Receiver Division, Appliance Park, Louisville, Ky. For six years he was chemist and metallurgist at Fairmont Aluminum Company and later was metallurgist at Tube Turns. Active in NACE, he is chairman of the Ohio Valley NACE Section.

CHARLES R. SOUTHWELL is a materials engineer for the Naval Research Laboratory. His work there is concerned with the study of deterioration of metals, woods and protective coatings in tropical environments. He is a member of NACE and has published several technical articles on protective coatings.

D. O. SPROWLS is a research engineer in the chemical metallurgy division of Alcoa Research Laboratories. His work has been on evaluation of the corrosion resistance and stress corrosion cracking of aluminum alloys. He is a member of NACE and ASM and has a BS in chemical engineering from Drexel Institute of Technology.

W. H. STEWART, former NACE president (1957-58), is affiliated with Sun Oil Company, Beaumont, Texas. He was a member of the original committee organized as the Mid-Continent Cathodic Protection Association, which subsequently became NACE. He also has served on NACE's Board of Directors (1955-58) and was the first chairman of Technical Group Committee T-2 on Pipe Line Corrosion.

J. SUNDARARAJAN is doing his doctoral work on the inhibition of corrosion of aluminum in the Electrochemistry Laboratory of the Indian Institute of Science, Bangalore, India. He has a BS and MS in physical chemistry and has published several papers on corrosion and related topics.

HENRY SUSS is a material engineer at General Electric's Knolls Atomic Power Laboratory, Schenectady, N. Y. He has a BS from New York University and an MA from Columbia University. He has been in corrosion work for 12 years.

L. LEROY SWAN is supervising engineer with the Electrical Coordination Group in the Chicago Area Transmission Maintenance and Coordination Section of the Illinois Bell Telephone Company. He is a member of NACE in the Chicago Section.

MAX A. SWIKERT is engaged in applied and fundamental lubrication and wear research at the National Aeronautical Space Administration's Lewis Flight Propulsion Laboratory in Cleveland, Ohio. He has a BS in mechanical engineering from Tri-State College.

DONALD E. TAYLOR is a research engineer at the Chicago Midway Laboratories. University of Chicago. He has a BS and MS in mechanical engineering from the University of Illinois. Formerly he was associated with the Armour Research Foundation.

R. D. TAYLOR is manager of the development department, American Smelting and Refining Co., Federated Metals Division. He has had 15 years' experience in design, manufacture, installation and appraisal of magnesium and zinc anodes in cathodic protection installations. He has been with Asarco for 20 years.

WILLIAM T. THEIS is affiliated with Internal Pipeline Maintenance Company, Odessa, Texas. He is an engineering graduate of Kansas State University. Before joining his present company in 1953, he was in ordnance research for a hydraulic and pneumatic equipment manufacturer.

F. W. THOMPSON is a materials engineer in the fields of protective coatings, thermal insulation and ceramics for the du Pont Company. He is a member of ACS and ASM and has a BS in ceramic engineering from Virginia Polytechnic Institute.

JOHN VAN BLADEREN has been with the Northwest Natural Gas Company since 1949 and has been corrosion engineer with the firm since 1955, working on design and installations of corrosion control for gas mains. He is an NACE member and is chairman of the Portland Section.

ELLIS D. VERINK, JR., is head of the chemical section, Development Division, Aluminum Company of America. He has been an NACE director and Pittsburgh Section officer. He has a BS in metallurgical engineering from Purdue University.

D. C. VREELAND, a member of NACE and ASM, is associated with the Applied Research Laboratory, U. S. Steel Corp., Monroeville, Pa. For the past year and a half he has been working on corrosion of steel in boiling water reactor environment with General Electric's Atomic Power Equipment Department. He has a BS from Antioch College and an MS in metallurgy from Ohio State University.

LEO J. WALDRON is head of the Marine Corrosion Section, Physical Metallurgy Branch in the Metallurgy Division of the U. S. Naval Research Laboratory, Washington, D. C. He has been with the Laboratory for the past nine years working on cathodic protection of naval vessels. He has a BS and MS in chemical engineering from Michigan State University.

JESSE D. WALTON, JR., is head of the ceramics branch of the Engineering Experiment Station at Georgia Institute of Technology. His work is in the fields of protective coatings for metals, ceramic-metal systems, thermal protective systems and high temperature technology, instrumentation and equipment design.

GEORGE W. WARDWELL is chief engineer and assistant to the vice president of manufacturing at Rolock Inc., Fairfield, Conn. He has a BS in mechanical engineering from Cooper Union Institute of Technology and is a member of ASM.

JOHN L. WEIS is affiliated with Diamond Alkali Co., Pasadena, Texas. Formerly he was with Phillips Chemical Company. An NACE member since 1952, he has a BS in mechanical engineering from New Mexico A & M College. His experience has been in maintenance of protective coatings on mobile, dock and other plant equipment in a chemical-salt water atmosphere.

W. C. R. WHALLEY joined the Iraq Petroleum Company in 1937. In 1945 he was appointed senior corrosion engineer. He has a MS in chemical engineering from the Imperial College, London.

D. E. WHITE is a materials application engineer at Westinghouse's Bettis Atomic Power Laboratory. He has a BS from the U. S. Merchant Marine Academy and a BS in metallurgical engineering from Case Institute of Technology.

EARL L. WHITE has been engaged in corrosion and chemical research at the Battelle Memorial Institute for the past 11 years. He has a BS in chemistry from Muskingum College and a MS in chemical engineering from Ohio State University.

F. C. WHITTIER is supervisor of protective coating research and development at Pittsburgh Coke and Chemical Company. Formerly he was with United States Testing Laboratories. An NACE member since 1951, he is a graduate of Bowdoin College.

W. LEE WILLIAMS is head of the metals division at the U. S. Naval Engineering Experiment Station. He has a BS in chemical engineering from Antioch College and has published several technical articles on stress corrosion cracking of stainless steels in hot water and steam environments.

PATRICK H. WOODS is a senior chemist in the Chemical Metallurgy Section of Reynolds Metals Company. His work has involved corrosion of automotive engines, pitting of aluminum containers, surface staining and finish specifications. He is a member of NACE and ASM and has a BS from Randolph-Macon College and a PhD from Baylor University.

Authors of Technical Papers, 16th Annual NACE Conference

Ploederl	Priest	Puckorius	Raleigh	Rama Char	Robinson
Rohrback	Roller	Rudolf	Ryzner	Schaschl	Shideler
Simon	Skinner	H. J. Smith	Southwell	Sprowls	Stewart
Sundararajan	Suss	Swan	Swikert	Donald E. Taylor	Theis
Thompson	Verink	Vreeland	Waldron	Walton	Wardwell

16th Annual Conference
AUTHORS

D. E. White

Earl L. White

Whittier

Williams

Woods

Chromium Metal Tubing Is Successfully Extruded

First successful extrusion of pure chromium metal tubing has been accomplished on an experimental basis. Chromium powder was cold-compacted into a mild steel container, heated, placed in a 1000-ton press and extruded over a mandrel.

The resulting chromium tubing was said to be nearly perfect in form with a density closely approaching the theoretical density of pure chromium metal. The experiment was conduced by James Wong, Nuclear Metals, Inc., with Union Carbide Metals Company furnishing the pure chromium powder.

Extruded chromium is hot-ductile but brittle at room temperatures. If it could be made ductile, metallurgists say the metals would be very useful as a corrosion and oxidation resistant material. Alloyed, it should have good strength at high temperatures and would be particularly useful for "skin" and structure of missiles and high speed aircraft and to contain exhaust gasses of rockets and jet engines. It might solve the problem of containing nuclear fuel elements.

Which Way Do Corrosive Fumes Blow?

Scientists Predict Long Range Weather To Help Industries
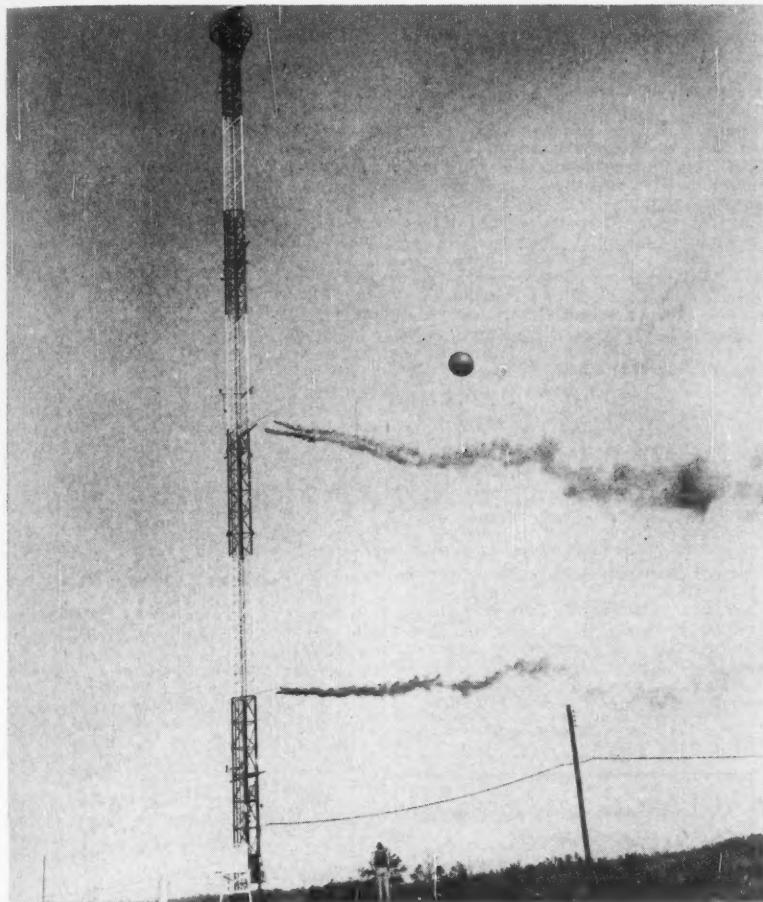
WHICH WAY will the fumes blow? Questions about the weather which can help industries affected by dramatic changes are being answered by research at Lockheed Aircraft's Meteorological and Applied Research Service, Marietta, Ga. This tower and smudge pot arrangement is used at Lockheed's Georgia Nuclear Laboratory near Dawsonville, Ga., to study intensity and direction of low level temperature inversions, emphasized by smoke from smudge pots.

When an industry considers a new location, the direction in which objectionable fumes will blow with what frequency becomes an important question. This and other weather information relative to industries and utilities are being studied and predicted with considerable accuracy by meteorologists at Lockheed Aircraft's Meteorological and Applied Research Service, Marietta, Ga.

These scientists have refined U. S. Weather Bureau information to predict atmospheric variable affecting missile trajectories at 80,000 foot altitudes. Using modern electronic analysis and diversified experience, they expect to develop new concepts of weather information to benefit the public, military programs, industry and agriculture.

Current proposals include a study of the rise and fall of rivers supplying water for hydro-electric public utilities, a long range low temperature forecast for a natural gas company to insure an adequate supply of gas during sudden temperature drops and a projection of these studies into other industries such as major construction projects, railroads and long distance truck lines.

The value of long range forecasting is illustrated by the recent power failure in New York City caused by an overload from air conditioners. If an adequate evaluation of the city's heat wave had been made well in advance, provisions for additional power could have met the emergency rather than risk suspension of necessary services.

Another case of the usefullness of long range weather forecasting is a public utility which depends on a combination of water power and coal. The company should know the anticipated precipitation in its watershed months in advance so that adequate but not an overabundance of fuel could be stored.

Tantalum Reactor Vessels Resist Most Acid Corrosives

Tantalum lined reactor vessels which will hold most acidic corrosives up to the limit of current test temperatures have been studied, according to a recent issue of "Industrial Research Newsletter" published by Armour Research Foundation of Illinois Institute of Technology.

The unit tested was a 30-gallon, 1000-pound vessel with ⅝-inch thick Type 430 stainless steel walls and a 0.030-inch tantalum lining.

Another item in the newsletter described improved specifications for vanadium which include reduction of hydrogen content by 90 percent and nitrogen and carbon contents by 50 percent. Analyses of 500 and 1000-pound lots showed the sum of carbon, oxygen, hydrogen and nitrogen to be about 0.1 percent.

A new stainless steel powder, according to the newsletter, can make stainless steel shapes of more than 95 percent theoretical density. Composition of powder is similar to Type 316 or CF-MO alloys. Mechanical properties of the sintered shapes closely approach those of wrought shapes. The powder may have potential uses in gears, bushings and other shapes exposed to aggressive corrosion.

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Portland Section's Corrosion Control Short Course will be held April 27-29.

Translations Continued Of 4 Russian Publications

Translation and publication of the 1959 issues of four leading Russian technical journals will be continued by the Instrument Society of America under a grant by the National Science Foundation.

The four Russian journals are Measurement Techniques, Instruments and Experimental Techniques, Automation and Remote Control and Industrial Laboratory. Both 1958 and 1959 issues are available.

Subscriptions and additional information can be obtained from the Instrument Society of America, 313 Sixth Ave., Pittsburgh 22, Pa.

BOOK NEWS

Proceedings of the Fourth Annual Underground Corrosion Short Course. Edited by R. E. Hanna, Jr. 644 pages, 6 x 9 inches, paper cover. October, 1959. Technical Bulletin No. 56. Engineering Experiment Station, West Virginia University, Morgantown. Per copy, $7.00.

Consists of the lectures given during the Fourth Annual Appalachian Underground Short Course at Morgantown, W. Va., June 2-4, 1959. The lectures were divided into: Basic, intermediate (pipe); intermediate (cable), advanced, water systems, pipe coatings, instruments, special topics and field demonstrations.

Information and data in the lectures is voluminous and for the most part, organized for practical application. Most of the lecturers are engineers with extensive experience in their respective spheres and qualified to give useful instruction.

The volume is liberally illustrated, has numerous tables and graphs, includes pertinent references at the ends of many lectures, and a registration list of those attending the course.

The 68 papers printed contain data likely to be useful to any engineer or engineering department concerned with underground corrosion. Although accessibility of the data would have been improved by a subject index, the fact that titles are explicit and most papers reasonably short makes it possible to locate needed information without excessive effort.

How to Invent by Forrest E. Gilmore. 89 pages, 5 x 7⅝ inches, cloth. 1959. The Gulf Publishing Co., Houston 1, Texas. Per copy $2.50.

A book designed to encourage engineers to use their capacity for invention in their work and otherwise. Written in an easy, relaxed style, the author describes the process of creative thinking, use of intuition and imagination, preparation for inventing, why it is helpful to learn to invent.

A system of making a first invention, general information about patent laws and some personal observations by the author on the thought processes essential for invention.

New Navy Cleaning Agent Helps Control Corrosion

A cleaning composition that acts as an anti-rust agent and which cleans fuel oil from electrical equipment without harming insulation, metal or humans has been developed by the Navy. Relatively harmless to electrical insulation, less flammable than the fuel oil, free of skin irritants and non-toxic, it has four components: hydrocarbon solvent, surfactant, penetrant, and water. An illustrated report titled "Salvage of Flooded Electrical Equipment" on this new cleaning process is available from Office of Technical Services, Department of Commerce, Washington, D. C.

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Houston Section's 5th annual corrosion control short course will be held January 28-29 at the Rice Hotel, Houston, Texas.

Corrosion of Iron in Distilled Water Depends on Crystallographic Face Exposed

Rate of corrosion of iron in distilled water depends on which of three principal crystallographic faces is exposed, according to experiments conducted by Jerome Druger of the National Bureau of Standards.

Initial experiments were conducted with iron single crystals grown in the shape of a ⅜-inch sphere from an ingot having 2460 ppm impurities. Flat surfaces were cut parallel to the 100 cubic 110 dodecahedral and 111 octahedral planes. The plane surfaces were polished mechanically then chemically.

A single crystal exposed for three hours in distilled water at room temperature sustained severest corrosion on the 110 plant. The 100 plant had approximately one-half and the 111 approximately one-quarter as many pits as the 100 plane. These results were similar to those obtained in previous studies of copper and aluminum.

Additional studies were made using iron of higher purity and specimens having large grains of many different sur-

face orientations. The same relation of severity of corrosion to crystallographic orientation obtained in each case.

In addition to attempting to find practical benefits, the experiments also had the goal of securing additional basic information on corrosive properties of metals and the mechanisms involved in the corrosive process.

Further details have been published in Mr. Kruger's article "The Influence of Crystallographic Orientation on the Pitting of Iron in Distilled Water," in the Journal of the Electrochemistry Society, Vol. 106, page 736, 1959.

Japanese Journal Publishes Papers

The following papers with corrosion interest were listed in Tetsu-To-Hagane Abstracts, No. 8, Tokyo: From the 55th Grand Lecture meeting, No. 14—Studies on the Mechanism of Corrosion Against Refractories From a Zebra Roof of a Basic Open Hearth Furnace by T. Ato et al. No. 72—Determining the Fundamental Conditions in Peening. 1. Relation Between the Dent Size, Density and the Fatigue Strength, by K. Kamishohara, et al. 73—Study of Acid Pickling. 1. On the Interference of Ferrous Sulfate, R. Kawabata et al. 75—Study on the Annealing of Steel Sheets for Galvanizing by T. Matumoto et al. 125—Effects of Nitrogen on Ni-Cr Alloys by R. Yode, et al. There were 128 papers presented.

At the 56th Grand Lecture Meeting. 75—Study on the Corrosion of Tin Plate by H. Asano et al. 105—Corrosion Testing Stainless Steels in an Experimental Oil-Distillation Apparatus by H. Hasegawa et al. There were 116 papers presented.

Copies in Japanese of these papers may be obtained from the Japanese Iron and Steel Institute, Naka-114-go-kan, 10 Marunouchi-2-chrome, Chiyodaku, Tokyo, Japan.

8 Corrosion Papers Given At Recent ASME Meeting

Eight technical papers on corrosion were presented at the Nov. 30-Dec. 4 annual meeting of ASME held in Atlantic City, N.J.

Five of the eight papers were given on a session dealing with corrosion in high pressure boilers. These included "Relation of Plant and Boiler Design to Corrosion in High Pressure Boilers." "Theories of Corrosion in High Pressure Boilers," "Relation of Plant and Boiler Operation to Corrosion in High Pressure Boilers," "Relation of Plant and Boiler-Water Chemistry to Corrosion in High Pressure Boilers" and "A Metallurgical Look Into the Future."

The other three corrosion papers were entitled "An Experimental Investigation of Fuel Additives in a Supercharged Boiler," "Corrosion of Superheaters and Reheaters of Pulverized-Coal Fired Boilers" and "External Corrosion of Superheaters in Boilers Firing High Alkali Coals."

PERIODICALS

Petroleum Today. Quarterly. First issue, Autumn, 1959. American Petroleum Institute, 1271 Avenue of the Americas, New York 20, N. Y.

Designed to acquaint readers with petroleum's achievements and its problems in supplying the basic source of energy, lubricants and other products. Purpose of the publication is to contribute to the public's understanding of the petroleum industry.

New Inventions Needed By Armed Forces

Over 300 new ideas from civilian inventors are needed to help solve some baffling problems facing the U. S. armed forces.

Some of the new ideas needed include a new propellant for long range space vehicle flights, a paper based material for clothing that can be worn and thrown away and instant sauces, dressings and condiments to make servicemen's dehydrated foods more palatable.

Other problems include seals needed to prevent gas leakage at exceedingly high pressure and heat and a method to prevent formation of water in small bore rifle barrels, perhaps by destroying surface tension.

The National Inventors Council, U. S. Department of Commerce, Washington 25, D. C., is soliciting suggestions to help solve the 300 different problems. A list of the problems can be obtained from the Council, which serves as liaison between the armed forces and the nation's civilian inventors.

Soybean and Linseed Oils Used for Aluminum Coating

Soybean and linseed oils provide tough, flexible coatings for aluminum and black, according to tests by Department of Agriculture chemists as reported by the Building Science News, publication of the Building Research Institute. The coatings resist abrasion, alkalis, acids and such solvents as alcohol, mineral oil and benzene and also withstand heat. Use of soybean and linseed oil films in adhesives, concrete and masonry paint is being studied by the Department of Agriculture.

New Adhesive for Rails

A thermosetting adhesive which bonds rail joints better than bolted joints has been developed by United States and Canadian railways. Present bolted rail joints often do not hold rail ends rigid.

Under load, rail ends batter and spall. The new thermosetting adhesive bonds by forming a molecular link between itself and the material bonded. The product was developed by Armstrong Cork Co.

English Corrosion Group To Give Technical Papers

Several technical papers on corrosion have been scheduled for presentation before the Corrosion Group of the Society of Chemical Industry in England for meetings in 1960:

January 13: Corrosion Problems of High Temperature Pressurized Water Reactors, by J. N. Wanklyn.

February 11: Recent Research on the Corrosion and Protection of Iron and Steel, by J. C. Hudson.

February 17: Adsorption on Electrodes and its Relation to Rates of Electrode Processes, by R. Parsons.

March 7: Corrosion Problems of High Temperature Pressurized Water Reactors, by J. N. Wanklyn.

March 16: The Mechanism of Inhibition in Neutral Aqueous Solutions, by D. M. Brasher.

April 6: The Presentation of Corrosion Information, by J. E. Jenkin.

April 21: Electrode Processes in Primary Batteries, by D. H. Collins.

Cooling Tower Rot Study

Redwood rot in large cooling towers on the Texas Gulf Coast has been studied by the California Redwood Association. It was found that chlorine used to control bacteria, fungi, molds and algae also reacted with the redwood to make it more vulnerable to damaging biological attack. A change to a non-oxidizing algaecide does a better job of killing microorganisms and acts on the wood as a surface disinfectant.

SEVEN-TON CYLINDER made of graphite will be cored to make sections for a large graphite tower in which elemental phosphorous will be burned for production of phosphoric acid. Five cylinders like the one above were produced by National Carbon Co., Division of Union Carbide Corporation. High temperature process equipment of essentially monolithic construction is made possible by production of fine grained graphite in this large cylinder. A minimum number of joints by use of the large sections gives simpler field erection and lower maintenance costs in fabricating structures for the chemical processing, nuclear, metallurgical and aircraft industries.

Flexible Rubber Pipe Is Solution For Corrosive Waste Disposal

An 1864-foot length of large diameter, flexible rubber pipe has been laid from the shore to the channel of the lower Delaware River as a discharge line for processing wastes from a chemical plant in that area.

The line was installed from an offshore dredge which first scooped a trench for the pipe on the river bottom. Fifty-foot flanged lengths of the rubber pipe, produced by Manhattan Rubber Division of Raybestos-Manhattan, Inc., Passaic, N.J., were bolted together with corrosion resistant bolts and nuts. The free end was lifted out of the water without disturbing sections already in place. After the flanges were joined, the dredge backed off one pipe length and dropped the newly attached length in place. Heavy cast iron collars bolted to each section anchored the line to the river bottom.

The use of flanges to join the pipe sections eliminated underwater bolting or welding that would have been necessary with a metallic pipe. Also, an unprotected metal probably would have had a relatively short service life in the Delaware River near the chemical plant because of salt water corrosion. A metallic pipe also would have been subjected to internal corrosion from the nitric and sulfuric wastes discharged through the line.

The rubber pipe is designed to withstand 100 psi. It has a nylon and steel wire carcass with a neoprene cover for protection against external damage. Depending on the tides, about 50 to 80 feet of the line can be exposed to weathering and floating debris.

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Over 20 million dollars was paid in 1959 to 39,000 employees of one company through the company's savings plan.

FLEXIBLE RUBBER PIPE sections are being bolted together as part of an 1864-foot line submerged in the lower Delaware River to discharge processing wastes from a large chemical plant. The cast iron collars shown were used to anchor the pipe in a trench scooped in the river bottom.

French Article Published On Cathodic Protection

"Cathodic Protection of Underground Iron Pipelines," an article giving some elementary information about underground corrosion and its prevention by cathodic protection is among several included in the March, 1959 issue of "Water and Industries" monthly information bulletin of the French Association for the Study of Water, 9, Rue de Phalsbourg, Paris 17, France. The bulletin is in French.

Polyethylene Glycol Flux Reduces Weld Splatter

A new flux medium made of polyethylene glycol has been formulated which reduces the bad spattering effects which cause the corrosion encountered with "killed spirit" (zinc chloride). The new fluxes spread much better and more uniformly than older fluxes and help solder penetrate further into joints, according to an article in Summer 1959 issue of "Tin and Its Uses," published by the Tin Research Institute in England.

When the new flux comes in contact with a hot soldering bit and molten solder, there is no violent boiling, and the flux spreads out smoothly and quietly, followed closely by the solder.

In a comparison of aqueous flux and the new glycol flux, the latter caused severe rusting and corrosion on the steel surface of specimens after standing for a few days. The polyethylene glycol flux showed no appreciable rusting or corrosion on the adjoining metal.

Wood destroying fungi were unable to attack specimens of wood which had been impregnated with certain organotin compounds, according to the Tin Research Institute.

Experiments at Delft, Holland, indicate that one of these compounds is particularly promising as a preservative.

Recent tests at the institute show that, if properly controlled, tin will suppress ferrite instead of being harmful in cast iron as was previously thought. Tin promotes the formation of the pearlite constituent without tending to cause massive cementite. This may lead to better wear resistant cast iron that would have good machinability.

Missile Parts Cold Cast From Fine Metal Powders

Cold casting of fine metal powders for use in missile components will be undertaken in a development program at Stevens Institute of Technology.

Known as slip casting, the new cold casting process consists of pouring a liquid suspension of fine metal powders at room temperatures into inexpensive porous molds. The objects to be cast become hardened when the metal powder suspensions lose their liquid through the porous walls of the mold. The fine metal particles adhere and take the shape of the surrounding walls. Then they are removed from the mold and sintered. Metals and alloys have been produced at the Stevens Laboratory in excess of 99 percent of their theoretical density.

Nickel Brightness Studied

The amount of light reflected by electroplated nickel depends on the size of microscopic peaks and valleys on its surface, according to research being conducted by Metallurgy Professor Rolf Weil.

When these bumps and crevices are smaller than the wave length of light, reflections occur. But when the bumps and crevices are larger, the metal appears dull.

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Plastic Conveyor Chains Used in Beer, Food Plants

Flat-top conveyor chains of the type used in bottling plants, canneries and other packaging operations are being molded of Delrin acetal resin, a new thermoplastic produced by Du Pont.

After nearly two years of field testing in breweries and food packing plants, the new chains indicated a normal service life estimated at two to four times that of metal conveyors. They did not corrode and required no lubrication.

Resilient and smooth, the Delrin chains did not develop burrs which might damage the bottom of cans causing rust to develop.

In another case, the chains operated nine months in hot pickle brine with virtually no wear or maintenance.

New TV Optical System May Have Uses for Inspection

A new instrument that permits a dentist to view any part of a patient's mouth, highly magnified, on a TV screen may have practical applications in industry to scan the inside of vessels too remote or too dangerous for other types of inspection.

The optical probe system consists of a bundle of optical fibers bound into a small whip-like cable with a lens arrangement at the probing end and coupled to a closed circuit TV camera at the other end. A bundle contains up to 10,000 of the hair-like fibers, each fiber transmitting a speck of light to the other end of the bundle where a picture made up of the thousands of light segments can be sent from the lens to the TV camera, then to the screen.

Plastics Program Available For Informal Group Use

Properties and applications of plastics available in standard shapes are explained in a half hour educational program, "Getting Acquainted with Plastics," offered by Cadillac Plastic and Chemical Co. Emphasis of the program is on 11 major thermoplastic families and the fiber glass reinforced plastics.

The program includes 10 minutes of color slides, numerous visual demonstrations, two table top displays, plus sample trays for audience inspection. Selections of technical and applications literature are provided. The informal program usually consists of a conversation between two speakers. Question and answer sessions may follow. A minimum audience of 20 is required. Arrangements for presenting the program can be made through Robert B. Jacob, president, Cadillac Plastic & Chemical Co., 15111 2nd Ave., Detroit 3, Mich.

Pollucite Deposits Found

Extensive deposit of high grade pollucite ore has been found in Southern Rhodesia, Africa. Tests indicate the deposit is one of the world's largest and will offer a supply of low cost pollucite, which is aluminum-cesium silicate, for cesium applications in such industries as glass and ceramics manufacturing, in welding rod fluxes and other uses in which silica is used with cesium.

Pipe Coated Inside And Outside in Automatic Plant

Forty miles of 30-inch gas pipe line is being coated inside and out in one operation at its Houston plant by Syd Culbertson, Inc. This probably is the first instance in which both of these operations have been done in large volume at one plant and at the same time.

Although the principal reason for cleaning and coating the pipe inside is to improve the C-factor, an additional benefit is derived in that it will not be necessary to pig the line after installation. Because the pipe being coated was stored outside for a long period, three cleaning passes were required on the inside before applying 1.9 mils dry thickness of an epoxy coating. Bill Schell, manager for Culbertson says he believes inside coating can be done at a price equivalent to the cost of pigging for many lines, if the inside coating is done at the same time as the outside.

The operation is highly mechanized. Pipe is unloaded from cars or trucks onto a gravity rack at the rate of 20 rail carloads a day. At the first station two cleaning passes are made. At the second station, one cleaning pass is followed by spray application of the epoxy coating. Technical supervision of the epoxy is provided by Coast Paint and Lacquer Co., Houston.

The 60-foot lengths are lifted by crane from the first gravity rack to a second gravity rack feeding into the outside coating and wrapping plant. Powered rollers move pipe lengths into the coating room where they pass over a gas flame to heat the steel, through a centrifugal blasting machine where the outside is cleaned, then to a priming head and then to the coating head where 4/32 inch asphalt is flowed on, followed by a 20-mil glass web, and asbestos-asphalt wrap and kraft outer wrapping. All joints are scanned by an electronic holiday detector.

Pipe entering the coating and wrapping room is kept turning by powered wheels. Joints follow one another automatically with no interval between. A special designed machine picks up the wrapped end emerging from the coating head and rotates it at the prescribed speed so coating proceeds without interruption from one joint to another.

The weld gap is automatically scraped and, after coating, the wrapped pipe is supported on the scraped ends only. The pipe moves by gravity, supported on weld gaps only, to a loader.

All coating operations are under cover. A large storage building, with fan driven circulation, is heated so pipe can be kept under controlled heat and humidity conditions when necessary.

Coated pipe stored outside is stacked on a river sand bed to give greatest bearing for the load.

Transportation is by rail, truck or barge on the Houston Ship Channel.

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Steps in Coating Pipe Inside and Outside

1. Pipe is unloaded from cars onto gravity rack. 2. Two cleaning passes are made here. 3. One cleaning pass and interior coating applied. 4. Joints lifted to external coating feed racks. 5. Joints are fed automatically into external coating train. 6. Gas flame heats joints just before entering centrifugal blasting box. 7. Joints emerge from blastering box (left) and are primed. 8. Primed joints enter coating head. 9. End-rotating machine draws coated pipe from coating head. 10. Coated joints are stacked on gravity rack and inspected.

226,800 copies of 25 NACE Technical Committee Reports were distributed in 1957. In 1958, 210,300 copies of 12 NACE Technical Committee Reports were distributed.

Meetings and Conferences Scheduled by ASME in 1960

Some of the meetings and conferences to be sponsored by the American Society of Mechanical Engineers are listed below:

ASME-AIEE Railroad Conference: April 13-14, Penn-Sheraton, Pittsburgh, Pa.

Maintenance and Plant Engineering Conference: April 25-26, Chase-Park Plaza Hotel, St. Louis, Mo.

Metals Engineering Division-AWS Conference: April 25-29, Biltmore Hotel, Los Angeles, Cal.

Design Engineering Conference and Show: May 23-26, Statler Hilton Hotel, New York, N. Y.

Petroleum Mechanical Engineering Conference: September 26-28, Jung Hotel, New Orleans, La.

Rubber and Plastics Conference: October 9-12, Lawrence Hotel, Erie, Pa.

Titanium Conference Is Planned for Sept. 12-13

The annual Conference on Titanium Metallurgy is scheduled for September 12-13 by New York University's College of Engineering.

This conference is one of four scheduled by the college for the summer. Others are as follows: Materials and Design, one week beginning June 27; Thermoelectric Materials and Devices, one week beginning June 13; and Conference on Vacuum Metallurgy, June 2-3.

Each conference will cover the most recent advances in its field and is intended primarily for practicing engineers.

Plastics Engineers Plan Conference for April 20

"Plastics in the Petroleum and Chemical Industries" will be the subject of the annual regional technical conference to be April 20 at the Hotel Texas in Fort Worth, Texas. Sponsored by the North Texas Section of the Society of Plastics Engineers, the program will be given in two concurrent sessions with papers on surface coatings and plastic structures, covering the most recent developments in both fields.

NACE member R. B. Bender of Tejas Plastics Materials, Fort Worth, and A. L. Barrier of Barrier Corporation, Mineral Wells, Texas, are on the program committee.

Annual Welding Convention

The American Welding Society will hold its 41st Annual Convention and Welding Exposition April 25-29, 1960, in Los Angeles, Cal. Additional information can be obtained from the Society at 33 West 39th St., New York 18, N. Y.

Process Patented for Use Of Refinery Acid Sludge

A patent on the process for use of refinery acid sludge has been granted to the inventor, G. Hunter Miley. The patent has been assigned to L. Sonneborn Sons, Inc., New York, N. Y.

The process, developed in 1955 at Sonneborn's refinery at Petrolia, Pa., converts the previously useless acid sludge into valuable products. The sludge, which results from treatment of petroleum products with sulfuric acid, is fed into a unique retort which produces sulfur dioxide and coke as its main products with a variable quantity of gaseous hydrocarbons. These gases are used profitably as part of the fuel to operate the retort.

Additional information on the process can be obtained from L. Sonneborn Sons, Inc., 300 Park Avenue South, New York 10, N.Y.

ASTM Committee Week

About 32 committees and subcommittees of the American Society for Testing Materials have scheduled meetings during the ASTM Committee Week, February 1-5, at Chicago's Hotel Sherman.

Instrument-Automation Conference Set Feb. 1-4

Over 60 technical papers will be presented during the February 1-4 Instrument-Automation Conference and Exhibit to be held in Houston, Texas. The conference will be sponsored by the Houston Section of the Instrument Society of America.

Theme of the conference will be "Process Control in the Electronic Era." Technical sessions will be devoted to concepts, techniques and applications of scientific equipment and methods used by various industries, with special attention given to the petroleum, chemical, aeronautical, missiles, electronic and process industries.

NEW PRODUCTS

Equipment Services   **Materials Literature**

Adhesives

B. F. Goodrich Industrial Products Co., a division of B. F. Goodrich Co., has produced a new adhesive to bond polystyrene foam to steel, aluminum, masonite, wood and other materials. The company also makes another adhesive, R-1083-T, for bonding polystyrene shapes to themselves, polystyrene sheet on steel, aluminum, formica and other materials.

"Adhesive Bonding of Aluminum," a new booklet available from Reynolds Metals Co., Richmond 18, Va., gives development of adhesives, advantages in modern applications, design of joints, types of adhesives and processing of adhesive joints.

Aluminum

Switchgear Housing made of extruded aluminum sections has been developed by Allis-Chalmers and Reynolds Metals Co., Richmond 18, Va. Elimination of painting for weather protection and varied design possibilities from the extrusions are some of the advantages derived from the use of aluminum. The housings also will be corrosion resistant and light weight.

Enamel Coated Aluminum Alloy Sheet in widths to 60 inches is being produced by Aluminum Company of America, 1501 Alcoa Bldg., Pittsburgh 19, Pa., at the company's Tennessee sheet mill. The enamel finish is available in thicknesses from 0.019 to 0.051 inches. The maximum width previously available was 42 inches.

Cleaners

Ultrasonic Model 100, produced by National Ultrasonic Corp., 111 Montgomery Ave., Irvington, N. J., is designed for small part cleaning applications in which average energy levels are required. It has a one-gallon heavy gauge, polished stainless steel tank with rounded corners to facilitate washing out of contaminents removed by ultrasonic energy.

LCR Purifiers for cleaning air and steam in lines to two inches in diameter are being produced by V. D. Anderson Co., division of International Basic Economy Corp., 1935 West 96th St., Cleveland 2, Ohio. The purifiers are designed to keep moisture and dirt from clogging and rusting expensive pneumatic and steam tools.

Aidco 10, a new organic chemical for de-activation of scale from boilers, heat exchangers, condensers, pipelines and refrigeration coils is being produced by Alloy Industries Development Co., 2211 Firestone Blvd., Los Angeles 2, Cal. The pH of Aidco 10 is between 9 and 11

and its specific gravity is 1.14. It is non-toxic, non-flammable, non-corrosive and practically odorless, according to the manufacturer.

Abrasijet, a new tool developed by Dowell, Division of Dow Chemical Co., P. O. Box 536, Tulsa, Okla., is claimed to remove scale and other deposits from the faces of producing formations in wells completed in the open hole and to perforate casing without the risk of shattering cement with explosives. Fluid carrying abrasive particles is pumped at high velocity through small jet orifices in the tool.

Blast Cleaning Equipment is listed in a new catalog available from Clementina Ltd., 2277 Jerrold Ave., San Francisco 24, Cal. The catalog includes valves, hose, nozzles, helmets, guns and other equipment used in blast cleaning.

Granular Mono Sodium Phosphate combining the desirable qualities of crystalline granular and powdered mono sodium phosphate has been developed by Monsanto Chemical Company's Inorganic Chemicals Division, 800 North Lindbergh Blvd., St. Louis 66, Mo. Because of the porous nature of the particles, the new phosphate product has the non-ionic holding power of a powder yet retains the excellent flow properties inherent in a granular material, according to Monsanto chemists.

Coatings, Organic

Ren RP-1125 Surface Coat is the designation for a new white epoxy surface coat formulation offered by Ren Plastics, Inc., 5422 S. Cedar Rd., Lansing 9, Mich. The material can be applied by putty knife, spatula, paddle or brush in thin coats or to $\frac{1}{8}$-inch thicknesses. It has a jell time from 18 to 22 minutes.

Lytron 680 Production, an acrylic-type binder for general outdoor latex paints, will be expanded when Monsanto Chemical Company completes its plant expansion at Addyston, Ohio.

Coatings—Application Equipment

Jiffy Mixer, an attachment for most chucked power tools, is designed to reduce mixing time for high viscous compounds such as puty or water-like emulsions. It can be used in open containers without splashing, according to the fabricator, Jiffy Mixer Co., Inc., 515 Market Bldg., San Francisco 5, Cal.

Complete Finishing Systems available from the DeVilbiss Co., Toledo 1, Ohio, are illustrated in an index published by the company. Included are spray guns, automatic spray coaters, industrial ovens, air compressors, etc.

Hollow Cone Spray Nozzles, injection molded of Tenite Butyrate by Austin

Manufacturing Corp., 305 Perry Brooks Bldg., Austin 1, Texas, are designed for air washers, cooling towers, spray ponds and evaporative condensers.

Dry Phosphatizing Process for coatings on metal parts has been developed by G. S. Blakeslee & Co., Chicago, Ill. Metal parts are given a phosphate coating by dipping or spraying with a trichlorethylene-based phosphatizing solution maintained at its 188 F boiling point. After the parts emerge from the machine, the solvent evaporates, leaving the parts dry and ready for painting.

Fittings

Stab-Clad, a line of pipe couplings developed by Dresser Manufacturing Division, Dresser Industries, Inc., Bradford, Pa., are factory coated and pre-assembled for joining mill wrapped pipe. Coatings are of coal tar epoxies and coal tar enamel.

New Pipe Line Products, Style 116 Casing Insulating Seal and Style 117 Casing Cradle, have been developed by Dresser Manufacturing Division, Bradford, Pa. The seal is comprised of two gaskets, one rims the casing end inside and out with a special inclined face on the portion of the gasket inside the casing. A second soft rubber gasket, also with an inclined face, fits around the carrier pipe. The carrier gasket is wedged by ramming the inside gasket tight against the outer casing gasket, the soft rubber facings forming a liquid seal as well as an insulating barrier. Dresser Casing Cradles have closely spaced hard rubber skids bonded to a pliable rubber impregnated fabric sheet to provide flexible support to the pipe.

Inhibitors

Immunol 438 for water suspendable method of magnetic particle inspection is described in a booklet available from Harry Miller Corp., 4th and Bristol Streets, Philadelphia 40, Pa. Immunol is used instead of kerosene or solvents as the vehicle for oil soluble and water soluble inspection phastes.

Kontol Corrosion Inhibitors for petroleum refineries are described in a new brochure available from Tretolite Company, division of Petrolite Corp., 369 Marshall Ave., St. Louis 19, Mo. Includes schematic diagrams, detailed engineering drawings and photographs and explanation of inhibitor application to various refinery systems.

Petronate CR, a rust preventive agent, is described in a bulletin available from L. Sonneborn Sons, Inc., 300 Park Avenue South, New York 10, N. Y. Application and test data plus U. S. Military specifications are included.

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NEW PRODUCTS

(Continued From Page 66)

Instruments

Miniaturized Electric Eyes for applications in counting, sorting, monitoring, assembling and automatic weighing are described in a booklet available from Photomation, Inc., 96 South Washington Ave., Bergenfield, N. J.

Portable Conductivity Tester designed to measure specific conductance of a solution in locations where electric power is not available is being marketed by Carma Manufacturing Co., 1879 Mullin Ave., Torrance, Cal. The hydroion meter is battery operated and reads ppm in saline or other solutions.

Resistor Wire for use in manufacture of precision wire wound resistors and potentiometers is described in a catalog available from Hoskins Mfg. Co., 4445 Lawton Ave., Detroit 8, Mich. Included are special tables and graphs covering the material's corrosion and wear resistance properties, high strength and electrical characteristics.

Single Probe Thickness Meter suitable for measurements on curved surfaces is available from O. Hommel Co., Pittsburgh 30, Pa. The miniature meter measures the thickness of a paint layer directly and without damage to the coating.

Mergers

Magnaflux Corporation, 7300 West Lawrence Ave., Chicago, Ill., developer of techniques and equipment for detecting hidden flaws in industrial materials and in non-destructive testing, will be operated as a subsidiary of General Mills, Inc.

Union Tank Car Company, 228 N. La Salle St., Chicago 1, Ill., has consolidated two of its fabricating divisions: Graver Tank & Mfg. Co., East Chicago, Ind., and the Lang Company, Salt Lake City, Utah. The new division will be called Graver Tank & Mfg. Co.

Harbison-Carborundum Corporation has been formed by the merger of Harbison-Walker Refractories Co., Pittsburgh, Pa., and the Carborundum Company of Niagara Falls, N. Y. The two companies have pooled their advanced refractories technology and financial resources to establish a jointly owned subsidiary for engineering, manufacture and sales of fused refractories. The new merger will operate Carborundum's plant in Falconer, N. Y.

Metals, Ferrous

Flat Stainless Spring Wire, precipitation hardened, has been introduced by National Standard Co., Niles Mich. The spring wire has the corrosion resistance of stainless steel combined with elasticity approaching music wire, according to the fabricator.

New Nickol Alloy Steels with very high strength have been invented in the re-search laboratories of International Nickel Co., Inc., 67 Wall St., New York 5, N. Y. Identified as 25 percent nickel steels, the new alloys achieve unique properties by simply air cooling from the heat treating temperatures. Yield strengths above 250,000 psi with 6 to 10 percent elongation and above 20 percent reduction of area are obtainable in section thicknesses, according to Inco engineers.

Stainless Steel Powder Mix that is flowable for producing corrosion resistant machine components and equipment is available from Union Carbide Metals Co., Division of Union Carbide Corp., 30 East 42nd St., New York 17, N. Y. Parts made from this steel powder have about the same corrosion resistance as cast and wrought stainless materials, according to the company.

Plants

Pittsburgh Coke & Chemical Company is expanding its Neville Island, Pa., sulfuric acid plant capacity by 70 percent.

Humble Oil & Refining Company has planned construction of a new lube oil processing plant and major expansion of two existing lube plants at its Baytown, Texas, Refinery.

Scientific Design Company, 2 Park Ave., New York 16, N. Y., will design and build three new maleic anhydride plants. They are for Monsanto Chemical Company in St. Louis, Mo., Pittsburgh Coke & Chemical Company at Neville Island.

NEW PRODUCTS

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Pa., and Monsanto Canada Limited, Ville La Salle, Montreal.

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Linde Company, division of Union Carbide Corp., is now operating a new liquid hydrogen plant at Tonawanda, N. Y.

Plastics

Chemically Inert Plastic Tape designed to seal and permanently lubricate threaded and coupled pipe joints has been developed by Minnesota Mining and Manufacturing Co., 900 Bush Ave., St. Paul 6, Minn. Called Scotchrap Dry Thread Sealer No. 4212, made with polytetrafluoroethylene, the tap is designed to withstand processing temperatures from the liquid oxygen range through that of super heated steam.

Glass Epoxy Laminate for use in normal and elevated temperature applications has been developed by Taylor Fibre Co., Norristown, Pa. Designated as grade GEC-111, the new laminate in a 1/8-inch sheet retained at least 68 percent of its flexural strength after one hour exposure at 300 F in company tests.

Rigid PVC Pipe has been used for natural gas distribution service by Illinois Power Company, Decatur, Ill. Kraloy DM grade, produced by Kraloy Plastic Pipe Co., Los Angeles, Cal., was used in 3/4-inch size.

Rigid PVC Ball Valves in piping systems subjected to corrosion have been developed by B. F. Goodrich Chemical Co., 3135 Euclid Ave., Cleveland 15, Ohio. The valves are made of Geon except for the seats and seals for resistance to oils, acids, alkalies and most chemicals.

Carbo Fix Repair Kit for making on-the-spot repairs in plant, mill and factory is available from Carboline Co., 32 Hanley Ind. Ct., St. Louis 17, Mo. The kit is a two-component, fast setting epoxy material that cures to a hard, tightly bonded patch, according to the fabricator.

Basic Teflon Shapes such as sheet, rod, tubing and tape are being produced at Crane Packing Company's new plant at Morton Grove, Ill. The plant is devoted exclusively to full scale processing of Teflon.

Flexi-Liners, made of flexible, laminated plastic for insertion in tanks so that liquids cannot touch tank walls, are being produced by the Flexi-Liner Company, P. O. Box 767, Pasadena, Cal. These one-piece removable liners can be made to fit vertical, horizontal or rectangular tanks with or without tops. They can be installed in metal, wood or cement storage tanks, according to the manufacturer.

Rexolite, a high dielectric constant styrene co-polymer which can be machined to close tolerances, is being used in the

NEW PRODUCTS

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engineering of coaxial transmission lines in the U. S. polar defense line, BMEWS. According to the manufacturer, Rex Corporation, West Acton, Mass., Rexolite is an effective gas barrier, is almost totally impermeable to moisture, resists crazing at temperatures below —50 F and can be cemented readily.

Neoprene Coating for fiber glass-base fabrics duct was developed by Vulcan Rubber Products Division, Reeves Brothers, Inc., 1071 Avenue of the Americas, New York 18, N. Y., to meet the severe impermeability requirements of a military specification. The light weight duct is intended for installations requiring optimum air flow efficiency and can be used for flow of liquids, gases, light solids and chemicals.

Solution Feed Manual Gas Dispenser Meter molded in 13 parts of polyvinyl chloride is being fabricated by United States Gasket Co., Plastics Division of Garlock Packing Co., Camden, N. J. The unit is used for industrial chlorination of water or for large commercial swimming pools.

Chemically Inert Pipe Crosses lined with Fluoroflex-T have been added as standard fittings in Resistoflex Corporation's (Roseland, N. J.) process piping line. These Type S crosses are immune to acids, caustics, chlorides, solvents, bleaching solutions, peroxides and phenols at concentrations from —100 to +500 F, according to the manufacturer.

Lucite Acrylic Sirup, a water-white fluid adapted to fiberglass production, is being used for industrial fencing by engineers at Du Pont's Chambers Works, Deepwater, N. J.

Six New Epoxy Resin Types for use in building, construction and maintenance have been developed by Sika Chemical Corp., 35 Gregory Ave., Passaic, N. J. Formulated especially for the construction industry, the epoxy compounds include joint sealants, bonding compound, patching compound, skid resistant surfacing for highways and corrosion resistant surfacing for concrete.

Pumps

New 316 Stainless Steel industrial positive displacement rotary pump is described in a catalog available from Waukesha Foundry Co., Pump Division, Waukesha, Wis. The manufacturer states there is less turbulence, pulsation, aeration and agitation on corrosion problem liquids of high or low viscosity.

Thermaflow 100, a reinforced polyester molding compound, has been used in a centrifugal pump developed for garden sprayers. A case history bulletin on the pump is available from Atlas Powder Company's Chemicals Division, Wilmington 99, Del. The pump is used in conjunction with a 10-gallon mobile sprayer for insecticides, liquid fertilizers and similar agricultural sprays.

Chempump Bulletin 1100, available from Fostoria Corporation, P. O. Box 35-7, Huntingdon Valley, Pa., describes the

company's line of seal-less pumps designed for leak-proof pumping. Includes design, operation and selection of pumps.

New Gear Pump Series for 3000 psi constant pressure and 4500 intermittent pressure service has been developed by Superior Hydraulics, Division of Superior Pipe Specialities Co., 15201 St. Clair Ave., Cleveland 10, Ohio.

Valves

Titanium Valves for dispensing, draining and sampling are being produced for service in the atomic energy, electronic and chemical industries by Eco Engineering Co., 12 New York Ave., Newark 1, N. J. According to the man-

ufacturer, the valves have resistance to corrosive media such as nitric acid, chlorine, nitric-sulfuric acid mixtures and chlorinated hydrocarbons.

Solenoid Valve, full ported with direct lift in port sizes from ½ to 3 inches and capacities from zero to 3,000 psi has been produced by Atkomatic Valve Co., Inc., 545 West Abbott, Indianapolis, Ind. The valves are available in bronze or stainless steel.

Super-Liner Supply Line Valve with threaded or compression connections has no metal valve parts in the water stream to eliminate the corrosion problem. The valve is manufactured by Walter L. Veatch, Inc., 1404 Thornton Ave., Elkhart, Ind.

MEN in the NEWS

Leonard B. Bruner, Jr., has joined Trionics Corp., P. O. Box 548, Madison, Wis., as senior research chemist.

J. C. Burkholder has been appointed manager of the resin division of Archer-Daniels-Midland Company, 700 Investors Bldg., Minneapolis, Minn.

Charles N. Chalfant has been promoted to senior product manager of metal finishing at Kelit Corp., 81 Industrial Road, Berkeley Heights, N. J.

Donald B. Erskine and **Andrew L. Foster** have joined the engineering department of Pittsburgh Coke & Chemical Co., Grant Bldg., Pittsburgh, Pa.

John P. Fraser, NACE member and chairman of the San Francisco Section, has joined Shell Development Company's laboratory in Houston, Texas, as corrosion supervisor.

Robert W. Gaines has joined the engineering sales staff of Water Service Laboratories, Inc., 615 West 131st St., New York 27, N. Y.

Charles W. Gavitt has been appointed plant industrial engineer at American Viscose Corporation's plant at Parkersburg, W. Va.

John W. Hawley, NACE member, has been appointed manager of the product development department for Chemtrol, 10872 Stanford Ave., Lynwood, Cal.

Gregory D. Hedden has been named technical director of Trionics Corporation's contract research laboratory at Madison, Wis.

Two NACE members are part of the staff of Magnachem Limited, a new Canadian company recently formed which will distribute corrosion control products. They are **D. G. Colls**, Magnachem president, and **William D. Roper**, who will be in charge of the Vancouver office.

Hugh E. Keeler, professor emeritus of mechanical engineering at the University of Michigan, has been appointed a director of the Hinchman Corporation, Francis Palms Bldg., Detroit, Mich.

William T. McLaughlin has been promoted to field sales manager for the protective coatings division of Pittsburgh Coke & Chemical Co., Grant Bldg., Pittsburgh, Pa.

E. J. McMullen has been appointed executive vice president and director of research and development for Sentinel Chemicals, Inc., 3011 San Jacinto, Houston, Texas.

Terry F. Newkirk has been appointed manager of the ceramics and metallurgy division of Trionics Corp., P. O. Box 548, Madison, Wis.

Curtis R. Pardee and **E. F. Anderson** have been appointed field service metallurgists for Crucible Steel Company of America. Mr. Pardee will have his office in Solon, Ohio; Mr. Anderson in Caldwell, N. J.

George O. Pfaff has been appointed marketing director at Wheelabrator Corp., Mishawaka, Ind.

Jack H. Powers has been named supervisor of metallography at Adams Carbide Corp., Kenilworth, N. J.

T. A. Rohlfsen has been appointed manager of the South Pacific Coast division of Oakite Products, Inc., 19 Rector St., New York City.

Howard W. Scaman has been named distributor sales manager of Dearborn Chemical Company, Chicago, Ill. **J. E. Clemens** was named advertising manager.

Thomas M. Reinhardt, NACE member, has been named southern district manager and **William R. Lamb** as manager of sales for International Paint Co., Inc., 628 Pleasant St., New Orleans, La. Mr. Reinhardt will be in charge of all Gulf and lower inland waterway operations.

James E. Starry has been appointed district manager for the Texas district of Nalco Chemical Co., Chicago, Ill. His office will be in Houston, Texas.

Kirk Usher has been appointed manager of tubular product sales for Aluminum Company of America. His headquarters will be in Pittsburgh.

Over 20 million dollars was paid in 1959 to 39,000 employees of one company through the company's savings plan.

CORROSION ABSTRACTS

INDEX TO
CORROSION ABSTRACTS

2. TESTING

2.3 Laboratory Methods and Tests

2.3.2, 6.4.2, 5.3.4
Clad Aluminum-Manganese Alloy Tubing for the Chemical Industries. (In Italian.) Alluminio, **27**, No. 3, 135-136 (1958) March.

Results of corrosion tests carried out with clad aluminum-manganese alloy tubing, continuously immersed in a 3 per cent sodium chloride solution, or exposed to the effects of salt spray, are reported. Cladding materials were aluminum-1 per cent zinc alloy and aluminum-1 per cent zinc-1 per cent manganese (Platergal). The good corrosion resistance of aluminum tubes internally clad with such alloys is demonstrated and their importance in the chemical industries is stressed.—ALL. 16455

2.3.5
Measurement of Wall Thickness of Metal from One Side Only, by Direct Current Conduction Method. J. G. Buchanan, F. W. Marsh and R. C. A. Thurston. Nondestructive Testing, **16**, No. 1, 31-35 (1958) Jan.-Feb.

Method involves measurement of "resistance" of area of metal with 4-electrode array; increase in "resistance" indicates decrease in thickness; theory of method and equipment used; testing procedure; applications to specific problems such as measuring corrosion thinning in steel plate, defects in plates and wall thinning of tubes.—BL. 16751

2.3.6, 6.6.6, 6.7.2
Etching of Refractories and Cermets by Ion Bombardment. T. K. Bierlein, H. W. Newkirk, Jr. and B. Mastel. Paper before Am. Ceram. Soc., Fall Mtg. Basic Sci. Div., Alfred, New York, Sept. 9, 1957. J. Am. Ceram. Soc., **41**, No. 6, 196-200 (1958) June.

Uranium oxide, aluminum oxide, porcelain, aluminum-aluminum oxide (SAP), nickel-titanium carbide base cermet (Kentanium K-152-B) and cobalt silicide-titanium carbide, titanium diboride cermet, typical examples of refractories and cermets, were satisfactorily etched by ion bombardment for subsequent optical and electron microscope study. Method used is similar to ion etching of metallic specimens. Representative optical and electron micrographs illustrate the applicability of method for developing microstructure of these materials.— INCO. 16471

3. CHARACTERISTIC CORROSION PHENOMENA

3.7 Metallurgical Effects

3.7.3, 6.3.20, 3.4.6
The Welding of Zircaloy-2. J. G. Purchas, D. R. Harries and H. Cobb. Brit. Welding J., **4**, No. 9, 412-421 (1957).

Zircaloy-2 is used for canning nuclear fuel-elements in water-cooled reactors, and sound welds are essential. Contamination by nitrogen during welding might cause severe corrosion in service. Specimens were welded in a controlled-atmosphere chamber under reduced pressure in highly purified argon. If less than one ppm of gaseous impurity was introduced above that contained in the argon into the chamber, corrosion-resistant welds were produced. The gaseous impurities in normal high-purity argon did not affect corrosion-resistance, nor did contents of 150 ppm nitrogen or 0.13 per cent carbon in the Zircaloy-2, but the introduction of 230 ppm nitrogen and 60 ppm oxygen caused inferior corrosion-resistance. Projection welding on a spot-welding machine gave fully fused joints under a variety of conditions, provided that a reasonable amount of upset was applied; the welds had satisfactory corrosion-resistance.—MA. 16251

3.7.3, 3.5.9
Brazing for High Temperature Use. G. S. Hoppin. Gen. Elec. Co. Steel, **141**, No. 9, 82-84, 86 (1957) August 26.

Nickel-chromium-silicon-boron, nickel-silicon-boron and nickel-chromium-silicon alloys make brazing a feasible method of fabricating assemblies used at extreme high temperatures. Alloys have good high temperature properties and assemblies brazed with them have a safe service temperature of 2000 F. Applications include many critical high temperature parts for automotive, aircraft and atomic energy equipment. Problems in operation of brazing process are erosion, brittleness of joints produced, adverse effects on parent metals and atmosphere purity requirements. Brazing of stainless steels and high-temperature alloys is discussed. Photos. —INCO. 16173

3.7.3, 6.7.2
Bonding of Cermet-Valve Components to Metals. G. M. Slaughter, P. Patriarca and W. D. Manly, Paper before Am. Welding Soc., Annual Spring Mtg., St. Louis, April 14-18, 1958. Welding J., **37**, No. 6, 249s-254s (1958) June.

Techniques and procedures used to bond cermet-valve components successfully to metals for high-temperature fluid service. Cermets studied contained varying percentages of titanium carbide, tungsten carbide, tungsten-titanium complex carbide, and niobium-tantalum-titanium complex carbide. Binder materials were primarily nickel and cobalt. Results of wetting tests on these cermets with different brazing alloys are presented, as are photomicrographs of most promising cermet-to-metal joints. Of brazing alloys tested, cermets containing large percentages of titanium carbide were adequately wet only by nickel-silicon-boron-iron, nickel-chromium-silicon-boron-iron and palladium-nickel alloys. Procedure for attaching cermets is described wherein a nickel or tungsten-base alloy cushion is brazed between cermet and Inconel to absorb stresses resulting from differential thermal expansion. Direct high-temperature bonding procedure is also discussed in which cermets of titanium carbide-nickel type are joined to nickel without use of separately applied braz-

ing alloy. Cermet is placed in intimate contact with the nickel and heated to approximately 1350 C in inert atmosphere.—INCO.   16735

3.7.3, 6.2.4
A Method of Controlled Slow Quenching of Impact-Test Bars. M. R. Meyerson and S. J. Rosenberg. Paper before Journées d'Automne, 1957. Rev. Mét., **55**, 318-322 (1958) April.

Description of method for heat-treatment of impact specimens, producing uniform and accurately-controlled slack-quenched microstructures and hardness at locations where notches are to be placed. Technique is a modification of end-quenching, and is considered of value in study of steels. Some data are presented for low-alloy chromium-nickel-molybdenum steels, showing deleterious effect of slack-quenching upon impact properties of some steels. In tempered steels, deleterious effect increases with decreasing slack-quenched hardness.—INCO.   16770

3.7.4
Solution of Graphite in Austenite. (In Russian.) K. P. Bunin and A. A. Baranov. Metalloved. I Obrabotka Metallov, No. 7, 15-18 (1958) July. Translation Available from Henry Brutcher, Technical Translations, P. O. Box 157, Altadena, California.

Experiments aimed at checking the correctness of various hypotheses advanced about the healing (filling) of pores resulting from graphite passing into solution in austenite, and at elucidating effect of the state of austenite on healing rate. Results, 2 figures.—HB.   16748

3.7.4, 6.3.19
Effect of Gaseous and Liquid Environments on the Brittle Fracture of Zinc Single Crystals. L. C. Weiner. Trans. Met. Soc. Am. Inst. Mining and Met. Engrs., **212**, No. 3, 342-343 (1958) June.

The cleavage strength of initially clean zinc single crystals was increased by immersion in a liquid or gaseous medium only if the medium reacted with the zinc to form an adherent surface film. 1 table.—ZDA.   16698

3.8 Miscellaneous Principles

3.8.2, 6.3.20
Electrochemical Behavior of Zirconium. pH-Tension Equilibrium Diagram of the Zirconium-Water System at 25° C. (In French.) M. Maraghini, P. van Rysselberghe, E. Deltombe, N. de Zoubov and M. Pourbaix. Centre Belge d'Etude de la Corrosion, Rapport Technique No. 45, January, 1957, 1-10. Available from Cebelcor, 21 rue des Drapiers, Brussels, Belgium.

On the basis of values of free energy of formation at 25 C. of the different constituents of the zirconium-water system, a diagram was constructed as a function of the pH and of the electrode voltage, representing the corrosion behavior and passivation of zirconium.— BTR.   14334

3.8.2, 3.8.4
Note on the Rate of Evolution of Hydrogen at a Magnesium Anode. J. H. Greenblatt. Can. J. Chem., **36**, No. 8, 1138-1140 (1958) August.

Recent work on the mechanism of the anodic dissolution of magnesium is reviewed and additional data on the temperature dependence of the rate of hydrogen evolution at magnesium anodes during electrolysis is given. It is concluded that the results obtained and the literature on this subject are explained more logically by a kinetic mechanism involving initial solution of a univalent magnesium ion followed by subsequent reaction of this ion with water than by postulating self-corrosion with hydrogen evolved at local cathodes. (auth)—ALL.   16517

3.8.4
Relationship Between the Rate-Controlling Step of the Mass-Transfer Process and Distribution of Corrosion Attack. J. L. Scott and J. W. Prados. Oak Ridge National Lab. U. S. Atomic energy Commission Pubn., CF-58-7-104, July 16, 1958, 9 pp. Available from Office of Technical Services, Washington, D. C.

Equations are derived which relate the distribution of corrosion attack or cold-zone deposits with the rate-controlling step of a system which exhibits a thermal-gradient mass transfer. Char-

acteristic distributions of attack and deposition are illustrated for thermal-gradient mass-transfer processes which are: 1) hot-zone controlled, 2) cold-zone controlled, and 3) both hot-zone and cold-zone controlled and the limitations of the method are discussed. It is concluded that both the hot-zone and cold-zone processes must be understood before the conditions leading to the least undesirable distribution of attack can be specified. (auth).—NSA.   16627

3.8.4, 3.2.3, 6.2.2
The Concentration Gradient of Iron-Ion-Vacancies in Wustite Scaling Films and the Mechanism of Oxidation of Iron. H.-J. Engell. Acta Metallurgica, **6**, No. 6, 439-445 (1958) June.

Concentration gradient of iron-ion-vacancies in Wustite scaling films is measured electrochemically. Films were obtained by oxidation of pure iron in oxygen at 650-1000 C. Concentration gradient of vacancies is constant over whole Wustite film. According to Wagner's theory of scaling a constant concentration gradient of mobile defects is expected under 2 conditions: diffusion coefficient of defects is independent of concentration; and thermodynamic activity of defects is proportional to concentration. Both cases were almost fulfilled in case of iron-ion-vacancies in Wustite. From measured gradients and velocities of oxidation of iron specimen diffusion coefficients of mobile defects are calculated. At higher temperatures these values are larger than diffusion coefficients obtained from measurements of self-diffusion of iron in Wustite. Marker experiments show that this difference may be due to participation of oxygen in transport of matter through Wustite. Graphs.—INCO.   16487

3.8.4, 5.8.2, 6.2.2, 4.3.2
Kinetics of the Dissolution of Iron in an Acid Medium. Pt. 2. Action of Certain Additives in Relation to Adsorbed Hydrogen. (In Italian.) Liliana Felloni and Giampaolo Bolognesi. Annali di Chimica, **47**, 996-1004 (1957) Sept.

Dissolution tests in hydrochloric acid were conducted on samples of Armco iron to observe interaction caused by addition of inhibitor on quantity of hydrogen adsorbed. Iron dissolved at end of tests was determined, and kinetics of evolution of hydrogen in presence of ethyl alcohol and of o-tolylthiourea, were followed. Action of inhibitors is characterized as deterrent to increase in overvoltage. 11 references.—MR.   15252

3.8.4, 3.2.3, 6.3.6
Studies on the Mechanism of Sulfurization of Low-Percentage Copper-Aluminum Alloys. (In Polish.) Lucjan Czerski, Stanislaw Mrowec and Teodor Werber. Arch. Hutnictwa, **2**, No. 2, 183-202 (1957).

The scale on alloys of copper with aluminum forms as a result of simultaneous and opposing processes of diffusion of copper and sulfur. The outer layer results from outward diffusion of copper ions and the inner layer from inward diffusion of sulfur.—BTR. 14612

3.8.4, 6.3.21
The Oxidation Characteristics of the Alkali Metals. Pt. I. The Oxidation Rate of Sodium Between —79° and 48° C. J. V. Cathcart, L. L. Hall and G. P. Smith. Acta Metallurgica, **5**, 245-248 (1957) May.

The oxidation rate of sodium was measured at five temperatures: —79, —20, 25, 35, and 48 C. The reaction rate in dry oxygen was found to be small, and the oxide films were highly protective. The observed oxidation data were not quantitatively consistent with any of the previously proposed theoretical rate equations; however, the general shape of the rate curves corresponded qualitatively to that predicted by the Cabrera-Mott oxidation model. It is suggested that the inadequacies of this model may be attributable to the inhomogeneity of thin oxide films formed on metals.—BTR.   14599

3.8.4, 3.4.9, 3.4.6, 3.7.4
The Reaction of Germanium with Aqueous Solutions. Pt. I. Dissolution Kinetics in Water Containing Dissolved Oxygen. Walter W. Harvey and Harry C. Gatos. Massachusetts Inst. of Technology. J. Electrochem. Soc., **105**, No. 11, 654-660 (1958).

The dissolution of germanium in water was studied as a function of oxygen partial pressure, temperature, crystallographic orientation and mobile-carrier density. It was found that, although thermodynamically feasible, germanium does not react with water, freed of oxygen, in the temperature range studied (up to 100 C). In the presence of oxygen the dissolution rate in pure water is a function of oxygen partial pressure, reaching a limiting value of the order of $1 \mu g/cm^2/hr$ at 35 C under oxygen partial pressures greater than approximately 0.5 atm. For a given oxygen pressure the dissolution rate is approximately trebled for a ten-degree temperature rise, the measured activation energy for the dissolution reaction being 19 ± 2 kcal/mole. The order of dissolution rates for the three principal crystallographic faces were found to be $(100) > (110) > (111)$. No effect on the dissolution rate was found to result from changes in mobile-carrier concentrations brought about by doping or illumination. From dissolution rates and potentials it is concluded that the dissolution process is under cathodic control and that the rate-determining step is the reduction of oxygen by germanium.   16719

3.8.4, 6.4.2
The Solution of Aluminum in Dilute Sodium Hydroxide Solutions. Part 3. A. G. Loshkarev. Zhurnal Prikladnoi Khimii (J. Applied Chem.) U.S.S.R., **30**, No. 12, 1861-1863 (1957). Available from Associated Technical Services, Inc., P. O. Box 271, East Orange, New Jersey.

A kinetic study showing the process to be governed by the rate of steady-state diffusion in the first period and by the rate of nonsteady-state diffusion of the alkali to the hydroxide formed on the metal in the second. 3 figures, 3 references.—ATS.   15346

3.8.4, 8.2.2
Corrosion and Iron Oxide Deposition Associated with Steam Power Stations. Edison Electric Institute Bulletin, **25**, 147-148 (1957) May.

Battelle research program determining solubility product and rate of decomposition of ferrous hydroxide over a range of temperatures and calculation of free energies and heats of reactions involved in corrosion.—MR.   16202

3.8.4, 4.7, 3.7.2, 3.4.8
Dilute Solutions in Molten Metals and Alloys. C. B. Alcock and F. D. Richardson. Acta Metallurgica, **6**, No. 6, 385-395 (1958) June.

Measurements were made of activity coefficients of sulfur in molten copper and in binary alloys of copper with gold, silicon, platinum, cobalt, iron and nickel at 1100-1500 C. Results indicate that thermodynamic properties of dissolved sulfur either in elementary metals or in alloys, cannot be explained solely on basis of electron chemical potential of metals or corresponding electron:atom ratio. Chemical approach was developed leading to qualitative relation between activity coefficients of sulfur in elementary metals and stabilities of metal sulfides. It leads to semi-quantitative relation between effect of alloying element at high dilution on activity coefficient of sulfur at low concentrations. Effect is function of activity coefficients of sulfur in the 2 elementary metals and activity coefficient of alloying element. Relationship was further developed to apply at high concentrations of alloying element and tested with success on variety of ternary systems. Tables, graphs.—INCO.   16469

3.8.4, 6.3.16, 6.3.9, 3.4.6
Kinetics of the Oxide Film Formation On Tungsten and Molybdenum. (In Russian.) V. A. Arslambekov and K. M. Gorbunova. Inst. of Physical Chemistry, Academy of Sciences, USSR. Doklady Akad. Nauk SSSR, **119**, 294-297 (1958) March 11.

Descriptions are given of the installation and the method for an accurate continuous analysis of the weight changes and oxidation processes in tungsten and molybdenum in a wide range of oxygen pressures and temperatures. —NSA.   16440

3.8.4, 3.4.9
Metal-Water Reactions. Pt. VI Kinetics of the Reactions of Water Vapor

with Strontium and Barium. Harry J.
Svec and H. Gene Staley. Iowa State
Coll., Ames. J. Electrochem. Soc., 105,
121-125 (1958) March.

Strontium and barium were reacted
with water vapor and the kinetics de-
termined in the temperature range 40 to
66 C for water vapor pressures from
17.5 to 92.5 mm mercury. The stoichio-
metry varied according to the reaction
conditions. For the strontium reactions
the products were hydrogen and stron-
tium hydroxide. For vapor pressures be-
low 44 mm the products of the barium
reactions were hydrogen and barium hy-
droxide while for pressures above 44
mm they were hydrogen and $Ba(OH)_2$
• H_2O. Manometric and gravimetric
methods were employed in the kinetic
studies. Both the strontium and lower
vapor pressure barium reactions followed
the parabolic rate law. At higher pres-
sures the barium reaction followed a
linear law. An activation energy of
-5.2 ± 0.2 kcal/mole was found for the
strontium reactions. The activation en-
ergy for the barium reactions was found
to depend on reaction conditions. Higher
temperature studies of the reactions be-
tween water vapor and strontium, bar-
ium, and calcium indicated that in cer-
tain temperature ranges above 100 C
completely protective coatings were
formed similar to those observed in the
oxidation of aluminum or chromium.
(auth)—NSA.

4. CORROSIVE ENVIRONMENTS

4.3 Chemicals, Inorganic

4.3.2
Corrosion Problems with Fuming
Nitric Acid. Rocket Fuel Requires New
Tests. M. G. Fontana. Ohio State Uni-
versity. Corrosion Technology, 4, No.
12, 423-424 (1957) December.

Corrosion fatigue of materials in fum-
ing nitric acid; cathodic protection tests
and stress-corrosion tests of certain
types of stainless steel; polarization
studies of aluminum and stainless steel;
studies designed to show concentration
cell corrosion, including corrosion by
sludged fuming nitric acid.—MR.

4.3.2, 6.3.19, 6.2.2, 6.4.2, 6.4.4
Investigation of the Zinc, Iron, Alu-
minum, and Magnesium Corrosion in
Aqueous-Dioxane Solutions of Certain
Electrolytes. (In Russian.) Iu. B. Kle-
tenik. Z Prikladnoi Khim., 30, No. 11,
1626-1632 (1957) November.

Studied corrosion in the following
solutions: sulfuric acid, hydrochloric
acid, acetic acid aqueous-dioxane solu-
tions, and in aqueous-dioxane solutions
of chlorides.—BTR.   15322

4.3.2, 4.4.7, 7.6.4
Sulfuric Acid Corrosion in Oil-Fired
Boilers—Studies on Sulfur Trioxide For-
mation. Donald R. Anderson and Frank
P. Manlik. Trans. Am. Soc. Mech.
Engrs., 80, No. 6, 1231-1238 (1958)
August.

Shows that a high sulfuric acid pro-
duction level can result from the pres-
ence of certain fuel ash constituents. A
pilot-plant size experimental oil-fired
boiler was used in studying the problem
of sulfuric acid corrosion in air heaters
and economizers.—BTR.   16452

4.3.3, 4.2.3, 6.2.5
Vanadium Pentoxide Corrosion of
Metals at High Temperatures. Pt. III.

Effects of Aluminum and Silicon on the
Corrosion-Resistance of Nickel-Chro-
mium Steels. (In Italian.) V. Cirilli and
A. Burdese. Metallurgia Italiana, 49, 320-
326 (1957) May.

Study of systems vanadium pentoxide-
silicon dioxide and vanadium pentoxide-
aluminum oxide. Latter contains $AlVO_4$
with incongruent melting point 695 C.
($\pm$ 10), which forms eutectic with vana-
dium pentoxide at $640 + 5$ (30 percent
alumina). Behavior at 700 of nickel,
chromium, and high-alloy nickel-chro-
mium steels containing aluminum and
silicon, with regard to attack by vana-
dium pentoxide is discussed.—INCO.
                                  14611

4.3.3, 6.2.5, 3.8.3
Corrosion Newsletter No. 4. J. L.
English. Oak Ridge National Lab. U. S.
Atomic Energy Commission Pubn., CF-
51-8-230, August 18, 1951 (Declassified
Feb. 14, 1957), 25 pp. Available from
Office of Technical Services, Washing-
ton, D. C.

Successful stagnant corrosion tests on
the corrosive effects of uranyl sulfate
were obtained with nitric acid-pretreated
stainless steel systems for as long as
six weeks of continuous operations at
250 C. Under conditions of the test, an
estimate of the oxygen available in the
system to maintain passivity was 0.28
cc/cm^2 of exposed surface area. X-ray
diffraction studies disclose the stainless
steel surfaces films to contain >80 per-
cent $\alpha \cdot$ ferric oxide and <5 percent
ferrous ferric oxide. Although the over-
all test results may be influenced one
way or another by the initial surface
condition of the "used" bombs, indica-
tions are that the oxygen requirement to
maintain passivity on nitric acid pre-
treated stainless steel surfaces is very
slight, $\leqslant 0.3$ cc/cm^2, under stagnant con-
ditions. (auth)—NSA.   16231

4.3.7, 6.2.2
A Study of the Mechanism of the At-
mospheric Corrosion of Iron in the
Presence of Sulfur Dioxide as Aggres-
sive Agent. (In Russian.) Z. A. Iofa and
G. G. Besproskurnov. Z. Fiz. Khim., 31,
No. 10, 2236-2244 (1957) Oct.

Initial corrosion rate and sulfur di-
oxide concentration in the atmosphere.
Analysis of the rust formed after 25 or
30 hours. Ratio of the equivalents of
sulfur and iron is close to 0.33. Electro-
chemical reactions at the iron surface
under a film of water.—BTR.   15325

4.6 Water and Steam

4.6.2, 3.8.4
Corrosion of Various Materials in
High Temperature Water. Final Report.
L. H. Vaughan and K. Mildred Fergu-
son. Babcock & Wilcox Co. for Knolls
Atomic Power Lab. U. S. Atomic En-
ergy Commission Pubn., BW-5250, June
25, 1957, 143 pp. Available from Bab-
cock & Wilcox Co., Research Center,
Alliance, Ohio.

An investigation of the corrosion and
deposition behavior of materials in high-
temperature and high-pressure water is
presented. The effects of surface treat-
ment and heat treatment on corrosion
were investigated. A fretting corrosion
test was conducted to evaluate the ef-
fects of relative motion or vibration of
fuel elements in contact with each
other. A detailed metallurgical examina-
tion of a number of materials tested is
included.—NSA.   16390

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4.6.2, 3.7.3, 6.2.5
Corrosion Resistance in 680 F. Water of Type 304 Stainless Steel Brazed Joints. J. M. Gerken. Knolls Atomic Power Lab. U. S. Atomic Energy Comm. Pubn., KAPL-M-JMG-8, March 29, 1957, 13 pp. Available from Office of Technical Services, Washington, D. C.

The corrosion resistance of several brazing alloys suitable for brazing type 304 stainless steel was determined qualitatively. The corrosion resistance in 680 F. SAR water of all brazes was good. Some brazing materials exhibited superior corrosion resistance in 680 F. water. These were a silver-copper eutectic BT, pure copper, pure gold, gold with 20 per cent copper, gold with 18 per cent nickel, copper with 20 per cent palladium and 3 per cent indium, 65 per cent palladium-35 per cent nickel, and ANP-81. (auth)—NSA.   14656

4.6.2, 6.4.2, 5.8.2
Corrosion of Aluminum in High-Temperature Water. Part III. Inhibition of Corrosion by Sodium Silicate. R. M. Haag and F. C. Zyzes. Knolls Atomic Power Lab. U. S. Atomic Energy Comm. Pubn., KAPL-1741, February 28, 1957, 18 pp. Available from Office of Technical Services, Washington, D. C.

The corrosion rate of 2-S aluminum in high purity water and in 0.01, 0.1 and 1 wt. per cent sodium silicate solutions has been measured at 200 and 250 C. A marked inhibition of corrosion was observed in the more concentrated solutions. (auth)—NSA.   14648

4.6.4, 8.9.5, 5.8.2, 1.3
A Quarter Century of Cooling Water Treatment for Naval Diesel Engines. F. E. Clarke. Naval Eng. Exper. Station. J. Am. Soc. Naval Engrs., 70, No. 2, 261-277 (1958) May.

Review covers: pioneer cooling system studies by the Navy; adoption of trisodium phosphate as first approved cooling water treatment; tests leading to use of soluble oils and experience with these inhibitors; evolution of alkaline chromate and its adoption as standard treatment for iron diesel engines; problems presented by aluminum engine blocks (cavitation effects); and return to soluble oils for protection of aluminum blocks. Mention is made of progress in waterside cleaning. Present research in cooling water treatment is enumerated. Treatment of aluminum engines with nickel and cobalt salts is latest item to appear. These treatments prevent corrosion by plating effects on waterside surfaces. Photographs, tables.—INCO.   16523

5. PREVENTIVE MEASURES

5.3 Metallic Coatings

5.3.4
Chromates as Applied to Hot Dip Zinc Coated Wire. M. S. Siddall. Wire and Wire Prod., 33, No. 7, 768-769, 809 (1958) July.

This is a general article describing three types of chromate treatment for improving the corrosion resistance of galvanized wire. The irridescent type is said to give the best protection, but if a bright finish is required the leached type of coating or the one-dip process must be used. It is emphasized that the operating conditions of the chromate bath should be carefully controlled.—ZDA.   16390

5.3.4
The Brightness of Electrolytic Deposits and Its Relation to the Internal and External Structures of the Deposits. K. M. Gorbunova and A. A. Sutyagina. J. Phys. Chem., USSR (Zhur. Fiz. Khim.), 32, 785-790 (1958) April.

Investigation of nature of brightness of deposits and its relation to internal and external structures of deposits. Data were obtained by study of effect of alternating current on electrocrystallization of nickel, zinc and cadmium from sulfate solutions with various surface-active agents. Comparison of data from structural studies on deposits (size, shape, structure of crystal faces and their mutual disposition) with results of measurements of reflection coefficient confirms assumption that brightness is independent of size and mutual orientation of crystals in deposit. X-ray and electron-microscope studies of zinc deposits led to conclusion that relief of individual crystals and deposits as a whole plays predominant part in appearance of brightness.—INCO.   16513

5.3.4
The Effect of Lead in the Galvanizing Bath on the Ductility of Galvanized Coatings on Steel. M. A. Haughton. British Non-Ferrous Metals Research Assoc., Research Rept. R.R.A. 1149, June, 1957. Sheet Metal Inds., 35, No. 374, 453-458 (1958) June.

Experiments were made to determine whether any effect of lead in bath upon ductility of coating could be observed in small hand-dipped sheet specimens galvanized under conditions of bath composition, temperature and time of immersion such as would be found in industrial strip or wire galvanizing plant. Variables included type of steel, bath composition and dipping time. Presence of lead was found to have no appreciable effect on ductility or weight of coating. Tables, photomicrographs.—INCO.   16489

5.3.4, 3.8.4
Some Problems in the Theory of the Electrodeposition of Alloys. Pt. VI: The Mechanism of Formation of Supersaturated Solid Solutions and Two-Phase Systems During the Electrocrystallization of Alloys. (In Russian.) Y. M. Polukarov and K. M. Gorbunova. J. Phys. Chem., USSR (Zhur. Fiz. Khim.), 32, 762-768 (1958) April.

X-ray study made on electrodeposited copper-lead, copper-silver and copper-nickel alloys. Formation of solid solutions or two-phase systems on cathode is associated with work of formation of new phase nucleus and in electrolysis is determined by electrode potential. It is shown that during electrodeposition of alloy at low polarization, formation of equilibrium or supersaturated solid solutions should be observed even when, according to phase diagram, components are not mutually soluble in solid form. Conversely at high polarization, two-phase systems may be formed even when continuous series of solid solutions are indicated by phase diagram.—INCO.   16611

5.3.4, 5.4.5
Paint Finishing of Hot-Galvanized Steel. (In French.) J. F. H. Van Eijnsbergen. Peint. Pig. Vernis, 34, No. 1, 3-9 (1958); English Translation in Ind. Finishing, 10, No. 117, 34-36 (1958); Account in Dutch in Verfkroniek 31, No. 6, 243-249 (1958).

The zinc surface must be previously prepared mechanically or chemically.

Choice of cleaning solutions and wash-primers are discussed. The galvanized surfaces can be renovated with zinc-rich paint.—RPI.   16714

5.3.4, 5.9.4, 2.2.2
Comparing Exposure Tests on the Corrosion Resistance of Passivated Galvanized Steel. (In German.) T. Biestek. Werkstoffe u. Korrosion, 9, 434-439 (1958) July.

Results of three-year exposure tests on galvanic zinc coatings passivated by 15 different chemical methods. Test atmospheres were industrial, urban, rural and marine. Considerable variation in corrosion resistance was observed with use of different acid and chromate solutions for passivating. Comparison of exposure and accelerated tests. 10 references.—MR.   16758

5.3.4, 5.4.2, 6.3.10, 4.3.3
Protective Coatings on High-Temperature Strength Alloys. V. A. Parfenov. Metalloved. I Obrabotka Metallov, No. 6, 33-37 (1958) June. Translation Available from Henry Brutcher, Technical Translations, P. O. Box 157, Altadena, Calif.

Localized corrosion of high-temperature strength nickel-base alloys (such as 20 per cent chromium, 2.4 titanium, 0.7 aluminum, balance nickel) for gas turbine blades, caused by presence of vanadium (pentoxide) and sodium in some fuels. Experimental study of protection given to such alloys by chromium electrodeposited in various thicknesses, or by enamel coating. Effect of such coatings on the endurance strength at 750-800 C (1380-1470 F). Preparation of specimens for fatigue testing; chromium plating and enameling practices; composition of enamel; relation between effec-

tiveness of enamel coatings and their firing temperature. Results of fatigue tests. Results of microexamination after fatigue testing; condition of the two types of coating; their performance with increasing testing time. 5 figures.—HB. 16615
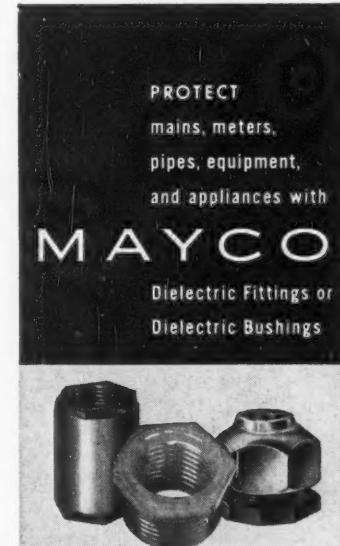
5.4 Non-Metallic Coatings and Paints

5.4.2
New Protective Silicate Coating for Metals. (In German.) Otto Loebich. Werkstoffe u. Korrosion, **9**, No. 7, 423-424 (1958).

By drying on to metals waterglass solutions and ageing the 0.2-several-μ thick silicious film, a protective transparent coating is formed called "Inverron." It protects silver, copper and copper alloys from air corrosion, prevents white rust on zinc and preserves the surface lustre. It protects against many aqueous solutions at room temperature and prevents the scaling of copper, iron and nickel between 150 and 300 C. A 5-10-μ coating has a breakdown potential of 220 V. At 400 C air passes through and scaling occurs beneath. It will not protect non-noble metals against strong acids or alkalis, nor iron and steel against flowing-water attack. The chemical nature of the film is described. —MA. 17478

5.4.2, 7.8
Enamelled Magnet Wire. H. L. Saums and W. W. Pendleton. Elect. Manufacturing, **60**, No. 4, 129-148 (1957).

The advantages and disadvantages of many types of wire enamel, including synthetic resin enamels, are considered. The properties of these materials are tabulated. 16 references.—RPI. 16342

5.4.6
Which Organic Coating? Howard R. Rothenberg. Materials and Methods, **45**, No. 6, 102-106 (1957).

The selection of protective coatings is discussed, and a chart shows how performance, decorative and cost requirements are met by 19 types of coating. Applications are illustrated and a typical specification given.—MA. 16324

5.4.5
Causes and Examination of Paint Defects on Rail and Road Vehicles. P. Baur. Ind.-Lack.-Betrieb, **26**, No. 4, 91-101 (1958).

The causes of paint film defects on the metallic and non-metallic surfaces of vehicles, classified according to occurrence at the substrate, in the film, or on the film surface, and relating principally to alkyd and N.C. finishes, are discussed. —RPI. 16470

5.4.5, 5.3.4
Organic Coatings for Zinc Surfaces. P. Costelloe and E. Page. Trans. Inst. Metal Finishing, **35**, 107-114 (1958); Bull. Inst. Metal Finishing, **8**, No. 2, 107-114 (1958) Summer.

Describes the results of atmospheric exposure and other tests on a wide range of paints applied to steel after zinc plating, both chromate and phosphate treated and hot dip galvanizing. It is emphasized that complete paint systems should be tested as the performance of a primer alone is not related to its performance when covered with a finishing paint.—ZDA. 16435

5.4.7, 8.9.2
Painting (a New Car). P. C. Bardin.

Industrial Finishing, **34**, No. 1, 62+7 pp. (1957).

The process includes pre-cleaning and surface smoothing, six-stage cleaning-phosphatizing, drying-off, application of prime coats, baking, wet sanding, drying-off again, tack rag wiping, and application of two coats of colored enamel followed by baking. Special features are the automatic contour spray painting machines for bodies and exposed parts and masking for two- and three-color jobs.—RPI. 16162

5.4.7
Multiple Facilities Speed Appliance Painting. T. A. Bottiggi. Ind. Finishing, **34**, No. 6, 20 + 8 pp. (1958).

Describes how sheet metal parts for a variety of products are cleaned, surface-treated, painted and baked on the different conveyor lines which serve four kinds of painting facilities—hand spraying, flow coating and two electrostatic painting set-ups.—RPI. 16460

5.4.8, 8.9.5
Plastics in Ships' Hull and Accommodation Spaces. J. West. Brit. Plast., **31**, No. 5, 192 (1958).

During recent years, investigation has been carried out on the use of vinyl resins for application to ships' hulls. Vinyl paints provide a good surface with high corrosion and fouling resistance and have a life of about two years. Costs, although initially higher, are offset by reduced maintenance. Epoxy resin paints are also being used, particularly inside cargo oil tanks. Other coatings used to protect small manufactured articles include polyvinyl chloride, nylon, polythene, polytetrafluoroethylene and neoprene-based self-curing rubber.—RPI. 16691

5.8 Inhibitors and Passivators

5.8.1, 6.3.19
Passivation of Zinc in the Gas Phase by Means of 1, 1-Dimethylethane-1-ol Chromate. (In German.) L. Cerveny. Werkstoffe u. Korrosion, **8**, No. 8/9, 543-546 (1958) August/September.

Tertiary butanol chromate was investigated as a vapor phase passivating agent for zinc. It was found that the resistance of zinc to corrosion after treatment depended on the length of time the zinc was exposed to the vapor. Investigations into the mechanism of the reaction between tertiary butanol chromate and zinc showed that the partial pressure of the air determines the velocity of passivation. Sometimes zinc specimens passivated in this way were found to have greater resistance to corrosion than those treated with solutions of chromic acid. 9 figures.—ZDA. 16793

5.8.2, 4.4.8
Lab Inhibitor Stops DEA Corrosion. J. D. Sudbury, O. L. Riggs and J. F. Leterie. Petroleum Refiner, **37**, 183-184 (1958) May.

Corrosion studies of alkanolamine systems revealed a peculiar type of threadlike corrosion called filiform corrosion. New inhibitor controls it in laboratory tests.—MR. 16668

5.8.3
The Use of Data from Electrocapillary Measurements in Studying Inhibitors of the Acid Corrosion of Metals. L. I. Antropov, et al. J. Applied Chem., USSR (Zhur. Priklad. Khim.), **31**, No. 10, 1497-1503 (1958).

Inhibitor efficiency is shown to be

directly related to a decrease in surface tension at the mercury-solution interface at a potential corresponding to the steady-state potential of the corroding metal. 4 figures, 30 references.—ATS. 16442

5.8.3, 3.6.8
Effect of Amines on Polarization of Iron Electrodes. A. F. Schram and L. R. Burns. Agriculture and Mechanical College of Texas. J. Electrochem. Soc., **105**, No. 5, 241-245 (1958) May.

An apparatus was designed and constructed which gives a measure of effect of organic amine salts on the polarization of iron cathodes in 1.0 normal sulfuric acid solution. Apparatus consists essentially of a Wheatstone Bridge circuit in which 2 of the ratio arms are electrolysis cells with a common anode and separate iron cathodes. Elements of the bridge are arranged in such a way that the electrolysis currents through the 2 cathodes can be measured simultaneously when the cathodes are at the same potential. Effect of the amine salts on the polarization of the iron cathodes was interpreted in terms of the apparent area changes brought about by adsorption of the amines on the surface of the cathodes. These apparent area changes were then compared with the percent inhibitor efficiencies of the amines, as measured by corrosion rate studies. Over the concentration ranges employed, the percent inhibitor efficiency for each amine is a linear function of the apparent percent surface area masked by the amine. Since the different amines showed considerable specificity in the relationship between percent efficiency and apparent percent area masked, it is concluded that the action of the amine as a corrosion inhibitor is more than a simple masking of certain portions of the surface of the corroding metal. Graphs.—INCO. 16651

5.8.4
On the Passivating Properties of Sulfate Ions. (In Russian.) I. L. Rosenfeld and V. P. Maksimchuk. Proc. Acad. Sci., USSR, Inst. of Phys. Chem. (Doklady Akad. Nauk), **119**, 986-989 (1958) April 11.

Sufficient quantities of sulfate ion act as passifiers for the stainless steel. The passivation effect of SO_4^- is conditioned by the presence of chromium and in a lesser degree by nickel. In the presence of chlorine and sulfate ions the processes on the electrode surface are assumed to be adsorptive and the sulfate ion passivation must be caused by its adsorption on the metal surface and its displacement of ions of chlorine.—NSA. 16623

5.8.4, 4.4.7
The Preparation of Highly Effective Rust Inhibitors by Fractionation of Mahogany Sulfonates. K. R. Fisch. Frankford Arsenal. U. S. Army Ordnance Corps. March, 1957, 18 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C. (Order PB 131231).

Very effective rust inhibitors for lubricants were prepared by the fractionation of commercial mahogany sulfonates, the products obtained from treatment of crudes for the manufacture of white oil. Fractionation was accomplished by continuous extraction of a solution of the sulfonate in 50 per cent isopropyl alcohol with petroleum ether. The rust-preventive effectiveness of the fraction of highest equivalent weight (548, calculated

as the sodium salt) was found to be approximately three times that of the original, unfractionated material. Infrared spectra indicated that the fractions were all similar and that the structure was that of an alkylated benzene sulfonate. Differences among the fractions were indicated to be in the size and possibly in the configuration of the alkyl side chains, and in the number of naphthenic rings.—OTS.   15262

5.9 Surface Treatment

5.9.1
Spray Cleaning, Pickling and Phosphating. A. J. Steiger. Metal Finishing, **56**, No. 3, 48-51 (1958).

Details of spray cleaning, pickling and phosphating by spray-jet methods are summarized. The phosphate coating obtained by the spray method using a solution of zinc monophosphate is not inferior in efficiency, and corrosion resistance to phosphate films obtained in hot phosphating.—RPI.   16664

5.9.1, 6.4.2
The Influence of Surface Pretreatment on the Atmospheric Oxidation of 2S (U. S. Alloy 1100) Aluminium. Philip M. Aziz and Hugh P. Godard. J. Electrochem., Soc., **104**, No. 12, 738-739 (1957) Dec.

The effect of several surface preparations on oxidation rate of aluminum was studied and marked differences were obtained. In some cases these are explained as being due to differences in true surface area. It was observed that surfaces containing amounts of embedded emery oxidize at rates which increase with the amount of emery in the surface.—MA.   15714

5.9.4, 3.5.9
Corrosion Resistance of Anodized Coatings Suffering from Hairline Cracks. (In German.) H. Neunzig. Aluminium, **34**, 390-391 (1958) July.

Influence of electrolyte temperature on susceptibility of bright anodized coating 5-15 microns thick to hot cracking and corrosion. High-purity aluminum-magnesium alloy sheet anodized at 17 and 25 C and then exposed to temperatures above 100 C. 15-micron coatings developed clearly visible hairline cracks which were susceptible to corrosion. High electrolyte temperature increased rate of corrosion when hairline cracks formed.—MR.   16625

5.9.2, 5.4.5, 6.4.2
Surface Treating and Protectively Coating Aluminum Windows. R. J. Anen. Industrial Finishing, **34**, No. 3, 28-30, 32 (1958).

All parts are passed through an immersion cycle of 7 tanks comprising alkali cleaning and etching solutions, chromic acid and water rinses prior to the finishing coat of methyl methacrylate lacquer.—RPI.   16772

5.9.4
Metallurgical Surface Treatment of Tinplate Produced in Liskovec (Czechoslovakia). J. Teindl and A. Hrbek. Hutnické Listy, **12**, No. 4, 329-332 (1957). Translation available from Henry Brutcher, P. O. Box 157, Altadena, California.

Properties of oxide layers (stannous and stannic oxides), with special reference to their effectiveness in resisting the formation of black spots. Corrosion

of tinplate in various acids. Modification of the Protecta-Tin process for protecting cans.—BTR.   16422

5.9.4
Anodizing Bath for Magnesium Alloys. M. W. Davies. Corrosion Technology, **5**, No. 9, 281-284 (1958) Sept.

The 'New Chrome' process for anodizing magnesium alloys is described. This process is carried out using alternating current in a bath containing potassium hydroxide, aluminum, potassium fluoride, trisodium phosphate and potassium chromate in the following proportions: 120 g/l potassium hydroxide; 13.5 g/l aluminum; 70 g/l potassium fluoride; 35 g/l Na_3PO_4. 12 water; 22 g/l potassium chromate. It is concluded that this anodizing bath offers advantages over the use of manganate in that the bath is cheaper and easier to

operate and, at the same time, the coatings have a better corrosion resistance. Coatings produced in this way are compared with those produced by the H.A.E. process.—ALL.   16493

5.9.4, 6.4.2, 8.3.5
Possibilities for the Practical Applications of Boehmite Films. (In German.) D. Altenpohl. Metall, **12**, No. 6, 503-507 (1958) June.

Surface protection by means of boehmite films is said to be most suitable for cooking utensils, containers and equipment used in the food industry, packaging material for food or other commercial goods and also for coating the interior of tanks and piping. The toughest boehmite films are obtained by subjecting aluminum to the effects of superheated water vapor or boiling water absolutely free from salt, and as free

from silicon dioxide, as possible. Additions of ammonium hydroxide or triethanolamine (0.1N) accelerate the growth of boehmite films, whereby a milky discoloration occurs. Recommendations are given concerning the application of continuous processes in industrial boehmite coating of aluminum products.—ALL.   16467

5.9.4

The Modern Chlorate-Accelerated Phosphating Bath. E. Heinzelman. Metal Finishing, **55**, No. 5, 61-64 (1957) May.

Conventional corrosion tests on phosphate coated steel panels show that coatings obtained from chlorate-accelerated zinc phosphate solutions have certain advantages over those from nitrate-accelerated solutions. They include a quicker rate of formation, a finer grained structure, less paint absorption, and better performance under impact and bend tests.—ZDA.   14654

6. MATERIALS OF CONSTRUCTION

6.2 Ferrous Metals and Alloys

6.2.2, 3.7.4, 8.8.5

High-Chromium-Molybdenum White Iron for Abrasion-Resistant Castings. T. E. Norman. Climax Molybdenum Co. Foundry, **86**, No. 6, 128, 130-131 (1958).

High-chromium white irons consist of structure in which hard carbides of Cr_7C_3 type exist in matrix of martensite and/or austenite. Molybdenum additions suppress pearlite formation and effectively help to retain Cr_7C_3 carbides. Result in turn permits use of higher carbon contents which normally improve abrasion resistance. Well-balanced composition for Climax Alloy 42 iron is: 3-3.5 carbon, 0.3-0.6 silicon, 0.5-0.9 manganese, 15-18 chromium, 2.75-3.25 molybdenum, 0.06 maximum sulfur, 0.10 maximum phosphorus. In sections up to 1 in., castings of this alloy are used preferably in as-cast condition. Stress relief at 400-450 F improves toughness without injuring abrasion resistance. Heavy-section castings should be heated slowly to 1900-1950 F, soaked 1 hour per inch of section, and cooled in air, followed by stress relief at 400-450 F. Table compares mechanical properties of Alloy 42 with those of pearlitic white iron. Wear-resistant applications for Alloy 42 include: sand pump impellers, wear shoes for spiral sand classifiers, flotation cell impellers, chute liners and grinding balls. In sand pumps and classifier wear shoes, high-chromium irons show 2-3 times wear resistance of martensitic white irons of 4.5 nickel-1.5 chromium type.—INCO.   16601

6.2.2, 3.2.2, 3.7.2

Oxidation of Fe-Al-C Alloys. (In Czech.) Miloslav Vkylicky, Bohumil Prenosil and Hanus Tuma. Hutnicke Listy, **13**, 490-495 (1958).

Study of alloys with varying aluminum and carbon content in the range of 900 to 1050 C. In some alloys oxidation is characterized by formation of blisters resulting from warping of initial protective layer. Oxidation continued at greater rate on spot of blister formation. Metallographic examination indicated that warping of initial protective layer is caused by volume changes connected with transformation of epsilon phase to gamma phase. This transformation was conditioned during oxidation by reduc-

tion of aluminum content in the base material in proximity to the surface. 16 references.—MR.   16677

6.2.2, 8.9.2

New Acid Resistant Nodular Iron. (In Russian.) Z. B. Shapiro. Liteinoe Proizvodstvo, No. 5, 24-26 (1958) May.

Development of corrosion resistant iron with 3 per cent carbon, 3 per cent silicon, 1 per cent manganese, 2.2 per cent chromium, 17.5 per cent nickel and 8.5 per cent copper for use in automobile motor cylinder blocks.—MR.   16640

6.2.5, 3.4.6, 4.6.2, 8.4.5, 3.4.3

Corrosion in a Large Stainless Steel Circulating Water System at 475° F. (WAPD-D-LOOP TEST). P. Cohen and V. W. Thompson. Westinghouse Electric Corp. U. S. Atomic Energy Commission Pubn., WAPD-RM-160 (Rev.), April 6, 1953 (Declassified March 18, 1957), 56 pp. Available from Office of Technical Services, Washington, D. C.

These tests confirm that forged 347 stainless steel piping corrodes appreciably in water at 475 F., containing small amounts of dissolved oxygen and hydrogen, forming primarily insoluble corrosion products of which a large part appears as "crud," finely divided magnetite, containing nickel and chromium oxides. At high dissolved hydrogen contents, the rate of formation of loose solid corrosion products is markedly decreased, and suspended "crud" concentrations are low. In the absence of radiation and at a crud concentration of 0.25 ppm., deposition on zirconium surfaces was essentially zero at 27-fps velocity, and measurable but not significant at a velocity of 6 fps. At low concentrations of crud of the order of 0.06 ppm., deposition was negligible even at 6-fps velocity. For reactor systems, where flux may cause deposition, operation under the conditions of the degassed run of this test would be likely to result in serious fouling of fuel elements. Operation with hydrogen appears to be a feasible means of eliminating the crud problem. (auth)—NSA.   15199

6.3 Non-Ferrous Metals and Alloys—Heavy

6.2.5

New Alloy Steels Beat Process Bugaboos. Pt. II. D. B. Roach and A. M. Hall. Battelle Memorial Inst. Chem. Eng., **65**, No. 11, 134, 136, 138 (1958) June 2.

A new group of stainless steels, known as precipitation-hardening steels, holds great promise in chemical process applications. The steels, combining high strength with corrosion resistance, are produced by a simple heat treatment. The steels contain elements such as aluminum, copper and molybdenum, which precipitate during the hardening treatment and combine the good corrosion resistance of the 17 per cent chromium, 7 per cent nickel type 301 stainless steel with strength properties of the 400 series. (auth)—NSA.   16593

6.3.5, 8.4.5, 8.9.1

A Columbium Primer. Chester T. Sims. Battelle Memorial Inst. J. Metals, **10**, 340-345 (1958) May.

The occurrence and economics, extraction, vacuum purification, alloying behavior, fabrication, mechanical properties and oxidation of niobium are discussed. High-temperature applications in

atomic energy and missile or jet engine applications are reviewed.—NSA. 16646

6.3.6, 6.7.3, 7.4.2, 4.6.4
Copper Alloys for Corrosion Resistance. R. V. L. Hall. Chem. Eng. Progress, **54**, No. 6, 51-55 (1958) June.

Difficult problems in corrosion have been solved by combining copper alloys with ferrous or other alloys as duplex tube or clad components. A difficult corrosion problem was solved by use of stainless over 70-30 copper-nickel duplex tube specially fabricated into nested combination heating and cooling coils. For the particular batch process involved stainless steel was suitable, but failures in the form of stress-corrosion cracking were encountered from inside surface due to high chloride ion content of raw water used for cooling. Since most of the copper alloys are highly resistant to cracking and corrosion from water and brine it was decided to solve problem by constructing coil from duplex tube with copper-nickel to circulating water side and stainless steel to product side. In addition to its superior over-all corrosion resistance this combination of duplex had about 25 per cent higher over-all corrosion resistance rate than straight stainless steel coils. Duplex with copper and 90-10 copper-nickel over stainless steel has recently been used to correct a severe pitting corrosion problem on cooling water side. Copper alloys are finding increasing use in protecting other alloys from corrosive conditions in which the performance of the latter is unpredictable and that of the copper alloys is predictable. Dezincification, pitting and cracking corrosion of copper alloys are discussed. Photos, graphs, photomicrographs.—INCO.
16725

6.3.6, 5.4.8
Brighter Prospects for Brass and Copper. Paul H. Margulies. Products Finishing, **22**, No. 4, 54-57 (1958).

A 10-60-sec dip in a 25 per cent ammonium persulfate solution at room temperature is claimed to remove stains, oxide films, etc. from brass and copper and provide a tarnish-proof (temporary) surface suitable for subsequent painting, electroplating or dip-soldering.—MA.
16544

6.3.10, 8.5.3, 8.4.3, 8.3.1
Paper, Gasoline, and Fertilizer: Three Cases for Nickel. H. O. Teeple. Ind. and Eng. Chem., **49**, No. 4, 75A-76A (1957).

The uses of nickel and nickel alloys in the paper, petrol and fertilizer industries are described. Results for corrosion rates of Monel in Kraft pulps and white water and nickel in tricresyl phosphate are given.—MA. 16426

6.3.15, 1.2.2., 3.5.8
Chemical Engineering Applications of Titanium. B. J. Connolly. Chem. and Process Eng., **39**, No. 7, 247-250 (1958) July.

One of the advantages of titanium over stainless steel and other corrosion resistant materials is its remarkable resistance to pitting, stress-corrosion cracking and corrosion-fatigue in chloride solutions. Table compares typical prices of titanium lined and stainless steel vessels. Although initial cost of titanium lined equipment may be higher than that of usual materials of construction, saving in maintenance costs and lost-time production, which can be achieved over a period of time, can more than offset this higher cost. Photos.—INCO. 16797

6.3.15, 3.6.6
Corrosion Resistance of Titanium. J. B. Cotton and H. Bradley. Chemistry and Industry, No. 22, 640-646 (1958) May 31.

Electrochemical characteristics; behavior of titanium in contact with other metals; resistance to stress cracking, erosion, and to certain halogens, acids, alkalis and chlorides; chart shows behavior of titanium dissimilar metal couples immersed in aerated seawater for 2500 hours.—BL. 16800

6.3.15, 3.7.4
Composition vs. Hot Strength Diagrams of Alloys of the Titanium-Vanadium-Columbium System. (In Russian.) V. S. Vlasov and I. I. Kornilov. Bull. Acad. Sci., USSR, Chem. Sci. Section (Izvestiya Akad. Nauk SSSR, Otdel. Tekh. Nauk), No. 7, 136-139 (1958) July. Translation available from Henry Brutcher, Technical Translations, P. O. Box 157, Altadena, Calif.

Study of hot strength of titanium-rich alloys in titanium-vanadium-niobium system. Phases present in this system. Preparation of alloys along three radial sections from titanium corner with vanadium/niobium ratios of 3/1, 1/1 and 1/3, respectively. Results. 3 figures.—HB. 16718

6.3.20
Zirconium and Its Alloys. C. Tyzack. U. K. Atomic Energy Authority, Industrial Group, Culcheth, Eng. Nuclear Eng., **3**, No. 24, 102-114 (1958) Mar.

A summary is presented of the metallurgical, physical, chemical, and nuclear data on zirconium, together with a brief discussion on the effects of irradiation and applications of the metal outside the nuclear industry. 73 references. (auth)—NSA. 15948

6.3.17, 3.5.4
Development and Properties of Uranium-Base Alloys Corrosion Resistant in High Temperature Water. IV. Radiation Stability of Uranium-Base Alloys. L. J. Jones, editor. Westinghouse Electric Corporation, Bettis Plant. U. S. Atomic Energy Commission, WAPD-127, Pt. 4, May, 1957, 117 pp.

Effects of pile irradiations on physical properties and corrosion resistance of uranium-9, —10.5, —12, and —13.5 w/o molybdenum, uranium-10 w/o niobium; and uranium-3.8 w/o silicon alloys. Changes in electrical resistivity, hardness, mechanical properties and crystal structure.—BTR. 15333

6.3.17, 4.6.2, 3.4.3
An Investigation of Uranium Corrosion in 100 C Water and 200 C Steam at Atmospheric Pressure. Oliver M. Stewart, Warren E. Berry, Paul D. Miller, Dale A. Vaughan, John B. Schroeder, Frederick W. Fink, and Charles M. Schwartz. Battelle Memorial Inst., U. S. Atomic Energy Commission Pubn., BMI-1271, June 19, 1958, 18 pp. Available from Office of Technical Services, Washington, D. C.

Material balance in atmospheric-pressure water and steam corrosion of uranium have been studied by examination of the phase composition and valence state of the corrosion product and by hydrogen-evolution measurements. The corrosion rates in atmospheric-pressure steam above 100 C are lower than those obtained in tests carried out in water with a hydrogen overpressure. The at-

mospheric-pressure-water corrosion product was found to be two phase: an oxygen-rich oxide, $UO_{2.2}$, and uncorroded metal particles. No hydride phase was detected, in contrast to previously reported evidence for hydride in uranium corrosion. The differences are explained

on the basis of hydrogen pressure in the reaction vessel. (auth)—NSA. 16635

6.3.20, 3.4.6, 4.3.3, 1.2.5

The Reaction of Zircaloy-2 with Water and with Uranyl Sulfate Fuel Solution. Final Report for June 3, 1957 through March 1, 1958. H. M. Higgins. Aerojet-General Corp. U. S. Atomic Energy Commission Pubn., AGC-AE-40, March 25, 1958, 70 pp. Available from Office of Technical Services, Washington, D. C.

The reaction of molten Zircaloy-2 spray with water and with uranyl sulfate fuel solution was investigated. It was concluded that there is no significant difference between the HRT fuel solution and water as an oxidizer for molten Zircaloy-2 droplets. Tests were performed to determine the extent of burning of Zircaloy-2 and zirconium in water, uranyl sulfate fuel solution, oxygen and steam at pressures up to 2000 psig. Self-sustaining reactions of these metals could not be initiated in the liquid media or in pure steam. Self-sustained burning was easily established in steam containing as little as 0.5 vol % oxygen. Moreover, when the burning of a half-submerged wire was initiated in the steam-oxygen zone and allowed to propagate into the liquid, the burning continued under water to a greater or lesser extent, depending on the temperature of the water. (auth)—NSA.   16511

6.3.20, 3.7.4, 3.5.4, 3.8.4

Physical Metallurgy and Properties of Zirconium-Uranium Alloys. A. A. Bauer, S. Kass and K. M. Goldman. Battelle Memorial Inst. and Westinghouse Electric Corp. U. S. Atomic Energy Commission Pubn., A/CONF.15/P/1785, 23 pp. Prepared for the Second U. N. International Conference on the Peaceful Uses of Atomic Energy, 1958. Available from Office of Technical Services, Washington 25, D. C.

The constitution and transformation kinetic behavior of uranium-zirconium alloys are presented. The system is characterized by complete solid solution between gamma uranium and beta zirconium at elevated temperatures and by the intermediate hexagonal epsilon phase which forms from this solution at about 600 C and contains approximately 50 wt per cent uranium. Oxygen and nitrogen have a pronounced effect on alloy constitution, stabilizing the alpha-zirconium phase and restricting the epsilon and beta phase regions. The high-temperature beta phase can be retained in alloys containing 20 to 70 wt per cent uranium by quenching, the beta phase decomposing by a nucleation and growth process to epsilon. Physical, mechanical and corrosion property data are summarized in tabular and graphic form and are related to alloy constitution and transformation kinetic behavior. The irradiation behavior of uranium-zirconium alloys is reviewed. The mechanical strength is found to be dependent not only upon composition but also upon the type, amount, and distribution of phases in the microstructure. The control of microstructure through heat treatment is of primary importance in controlling strength since the decomposition products of the high-temperature beta phase are particularly sensitive to uranium content. The aqueous corrosion behavior is found to be influenced by water temperatures, amount and distribution of phases, oxygen content and cooling rate from the beta phase region. The irradiation behavior appears to be

relatively insensitive to microstructure but is markedly dependent on irradiation temperature. Low volume changes are exhibited by alloys containing up to 80 wt per cent uranium when irradiated at low temperatures. Irradiations in excess of 600 C, at beta phase temperatures, are found to produce volume increases as high as 50 per cent per 1 at. per cent burnup. (auth)—NSA. 16746

6.3.21, 3.8.4

Reaction Rate of Solid Sodium with Air. William H. Howland and Leo F. Epstein. Knolls Atomic Power Lab. Ind. Eng. Chem., **49**, 1931-1932 (1957) Nov.

This study was undertaken to determine the influence of temperature and composition of solid sodium on its rate of reaction with air. A quantitative reexamination was made of the observation that the speed of reaction of alkali metals and air is markedly dependent on purity. The rate of reaction is greater for filtered sodium than for the relatively pure distilled material, particularly at lower temperatures, and the difference between the rates tends to vanish at the melting point of the metal. These experimental results suggest that the reaction is catalyzed by the presence of small amounts of impurity and that the catalysis reaction has a high energy of activation. (auth)—NSA.   16187

6.3.21, 3.7.2, 3.7.3

Thorium and Thorium Alloys Preliminary Corrosion Tests. Arnold R. Olsen. Oak Ridge National Lab. U. S. Atomic Energy Commission Pubn., ORNL-1066, December 19, 1951 (Declassified March 4, 1957), 21 pp. Available from Office of Technical Services, Washington, D. C.

The corrosion resistance of thorium and thorium alloys containing from 2 to 6 per cent chromium, niobium, titanium, zirconium and titanium-zirconium in distilled water at 95 C was investigated. The true effects of the various alloy additions could not be determined because of the more marked effect of cold working. It was found that a sample cold rolled 75 per cent and annealed would show a tenfold higher weight change over an otherwise identical sample cold rolled 68 per cent and annealed; or a decided loss in weight compared to a relatively small gain. (auth)—NSA. 16267

6.3.5, 3.7.2, 3.5.9

Oxidation Resistance of Niobium-Base Alloys. H. J. Cleary. Nuclear Metals, Inc. U. S. Atomic Energy Commission Pubn., NMI-1157, July 13, 1956 (Declassified July 21, 1958) 26 pp. Available from Office of Technical Services, Washington, D. C.

A program has been under way for the development of a niobium-base alloy with oxidation-resistant properties above 2000 F (1093C); a 1000-fold improvement over the oxidation resistance of unalloyed niobium at these temperatures was desired. A considerable number of binary and ternary niobium-base alloys have been investigated for oxidation resistance at 980 C. The following alloying elements were found to be somewhat beneficial when added in sufficient amounts to niobium, aluminum, chromium, titanium, tin and cobalt. Addition of binary elements lowered the oxidation resistance of niobium: vanadium, copper, magnesium, uranium, zinc and silicon. Elements which had little effect on the oxidation rate of the base metal were beryllium, nickel, iron and manganese. Ternary alloys with better

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oxidation resistance than unalloy niobium were: niobium-20 wt per cent chromium-6 wt per cent aluminum, niobium-10 wt per cent chromium-2 wt per cent aluminum, niobium-20 at per cent titanium-5 at percent beryllium, and niobium-25 at per cent titanium-10 at per cent aluminum. A ternary alloy with low resistance was niobium-25 at per cent chromium-5 per cent beryllium. The best of these binary and ternary alloys (niobium-25 wt per cent titanium, niobium-20 at per cent titanium-5 at per cent beryllium, niobium and titanium-10 at per cent aluminum) showed less than a 40-fold improvement in the oxidation rate of unalloyed niobium at 980 C (1800 F). (auth.)—NSA.

6.3.6, 3.2.2, 4.4.6
Brittle Failure of 5% Aluminum Bronze—A Case History. A. C. Hamstead. Union Carbide Chemicals Co. Ind. & Eng. Chem., **50**, No. 10, 87A-88A (1958) October.

Mechanism of failure of 5 aluminum bronze in hydrocarbon gas service is suggested. Why corrosion of single phase aluminum alloys (5 and 3.4 aluminum) was predominantly intergranular while it was uniform "layer-type" "dealuminification" in duplex aluminum bronze (9.5 aluminum), is open to speculation. Phosphor bronze alloys were not susceptible to selective attack or intergranular corrosion in this environment as were aluminum bronzes. Both of these alloys have good resistance to scaling and oxidation at accelerated temperatures and have about equal tensile and yield strength which is much higher than that of copper. Alpha aluminum bronzes—plain or modified with 5.0 nickel—and phosphor bronzes are widely used in refinery service, in heat exchangers and for condenser tubes and tube sheets. Photomicrographs.—INCO.

17349

6.3.8, 3.7.2, 4.4.7
Corrosion of Lead-Base Babbitt Metal. C. I. R. McDougall and E. Klar. Ontario Hydro Research News, **9**, 19-22, 26 (1957) July-Sept.

Alloys No. 7 and 8 with 5 and 10 per cent tin resisted corrosion under all conditions. Alloy No. 15 with 1 per cent tin resisted corrosion under most circumstances, even when in contact with highly acidic oil. However, when water was present in same oil, a very marked interaction was evident, oil deteriorated rapidly and babbitt surface was corroded.—MR.

17148

6.3.8, 8.1.2, 3.5.4
Lead in the Building Industry. (In French.) Jean Chauvin. Corrosion et Anticorrosion, **6**, No. 6, 223-228 (1958).

The favorable properties of lead in building applications are discussed, and its use as a shield against radioactivity is also considered. Special reference is made to corrosion-resistance.—MA.

17210

6.3.10, 3.5.9
High-Temperature Mechanical Properties of Hastelloy B and Hastelloy W. C. R. Kennedy and D. A. Douglass. Oak Ridge National Lab. U. S. Atomic Energy Commission Pubn., ORNL-2402, Nov. 28, 1958, 81 pp. Available from Office of Technical Services, Washington, D. C.

The high-temperature properties of Hastelloys B and W were investigated. The results are discussed in terms of creep, microstructures, effects of aging

and effects of environment. The alloys were found to have good high-temperature strength and resistance to fused-salt corrosion; however, a severe loss of ductility at high temperature restricts their use. Graphs, photomicrographs, and phase diagrams are included.—NSA.

17367

6.3.10, 3.7.2
Studies on the Heat-Resistant Properties of Nickel Solid-Solution Binary Alloys. (In Japanese.) Masozo Okamoto and Senri Okada. J. Japan Inst. Metals, **21**, No. 9, 544-548 (1957).

Data are given on solid-solution-hardening, work-hardening, recrystallization softening temperature and corrosion-resistance for nickel, alloys with titanium, silicon, molybdenum, aluminum, manganese, chromium, tungsten, iron, copper and cobalt.—MA.

16990

7. EQUIPMENT

7.1 Engines, Bearings and Turbines

7.1
Electra Landing Gear Designed for 12,000 Touchdowns a Year. J. B. Beach. Lockheed Aircraft Corp. Aviation Age, **29**, No. 6, 40-45 (1958) June.

Description of landing gear for Lockheed's Electra turboprop transport. Most of structural parts are machined from 4340 steel forgings. Eight major components are high heat treat steel good for 260,000-280,000 psi ultimate tensile strength. Most of other steel parts are heat treated to 190,000-200,000 psi UTS. Nose strut cylinder is one-piece Uniweld cylinder and pistons and axles are one-piece Uniwelded high heat treat steel. Upper bearings are aluminum bronze.—INCO.

17154

7.1, 4.7, 3.6.6
Some Preliminary Tests on Bearing Materials to Operate Under Liquid Sodium-Revised Interim Report—June 1954. D. F. Elliott, E. Holland and K. A. Tomblin. Gt. Britain Atomic Energy

Research Establishment, Harwell, Berks, England, April 23, 1956 (Declassified Sept. 17, 1957), 37 pp.

The object of these tests is to determine the most suitable materials to be used in the construction of bearings for a 50 H.P. Sodium Pump. The most critical period of operation for these bearings is during start up, when a condition of 'boundary lubrication' will

exist, and metal-to-metal contact will occur between the rotating shaft and the bearing until the speed of the pump shaft is sufficient to give true 'hydro-dynamic lubrication' by creating a continuous film of sodium within the bearing. The characteristics required for a suitable pair of bearing materials are given. The results of these tests may also be useful in the selection of materials for use as rubbing surfaces in reactor mechanisms which are required to operate submerged in liquid sodium or sodium-potassium alloy. (auth)—NSA. 15771

7.1, 8.9.2, 4.4.7, 2.3.9

Piston Ring Wear. J. H. Deterding and J. R. B. Calow. Automobile Engr., 48, No. 10, 378-381 (1958) Oct.

Discussion of application of radiotracers to measurement of engine wear in moving vehicles. Investigation is described of corrosive wear caused by condensation of acidic combustion products on cold rings and cylinder walls. Lubricant employed for this experiment was a mineral oil without additives. For some time after starting of the car, a high wear rate prevailed, but as the engine warmed up, corrosive wear was reduced and the wear rate fell to a lower level. After running for about an hour the car was stopped and the engine again cooled down with cold water. At this state a small quantity of anti-wear additive was introduced into the lubricant. Cooling was continued for a little over an hour and a second cold start was made. It was seen that there was not a period of high wear after this start, since corrosive wear was suppressed by the additive. The work has shown that with the aid of radiotracers it is possible to record ring wear continuously and automatically in moving vehicles. Tables, graphs.—INCO. 17281

7.7 Electrical, Telephone and Radio

7.7, 5.4.10

The Protection of Overhead Electricity Conductors. J. A. Airey. Corrosion Prevention and Control, 5, No. 4, 44-45 (1958) April.

New product, Shell Ensis Compound 356, will be used to protect steel-cored-aluminum (s.c.a.) long-span electrical power transmission cable across estuary of River Severn. Steel wires of this composite conductor are galvanized, and electrolytic couples may be set up between the zinc and aluminum, particularly in coastal regions. Examples of severe corrosion of outer aluminum strand, of severe corrosion of s.c.a. conductor and advanced electrolytic corrosion of an older type conductor are shown.—INCO. 17176

7.7, 7.1

Potentiometers for Missile Systems. W. J. MacDonald. Technology Instrument Corp. Missile Design and Development, 4, No. 11, 22-24 (1958) Nov.

Active development of new approaches to potentiometer design was aimed at utilization of thin metal films as resistance elements. Metallic film is deposited upon substrate by condensation of metallic vapor in a vacuum chamber. Basic material is Nichrome metal which, in wire form, is wound over a tungsten filament evaporator within the vacuum chamber. Under a pressure of about 1 millionth of a millimeter of mercury, the nickel-chrome is evaporated by electric heating of the tungsten element. Resistance of potentiometers made with Nichrome alone tends to increase with time under sustained operating ambient temperatures exceeding 150 C. This increase is due to oxidation of the Nichrome. Partial oxidation of Nichrome produces an inherently higher resistivity. This is offset by the lower resistivity of rhodium and by its freedom from oxidation with temperature increase. In addition, thicker films are deposited than would normally be required for potentiometers intended for service at lower temperatures. Metal films which are resistance-stable up to 300 C are produced by condensation of mixtures of rhodium and germanium vapors. Rhodium is characterized by a positive temperature coefficient and relatively low resistivity. Photos.—INCO. 17467

8. INDUSTRIES

8.2 Group 2

8.2.2, 7.2

Power Piping Design. F. M. Kamarck. Burns and Roe, Inc. Heating, Piping and Air Conditioning, 30, No. 11, 95-104 (1958) Nov.

Description of the Thos. H. Allen Electric Generating Station in Memphis. Material selection was based on 1053 F design temperature. It was decided to use a chromium-molybdenum alloy (2¼ chromium, 1 molybdenum) since it had the highest allowable stress value at the design temperature and the greatest accumulated record of experience. Two pipe system layout with a cross-over uses hollow forged chromium-molybdenum pipe for straight runs, with turned-and-bored piping for bends. Photos.—INCO. 17370

8.2.2, 7.4.2, 6.4.2, 4.6.2

A Report on a Plant Installation of Aluminum Condenser Tubes. W. A. Pollock. Wisconsin Electric Power Co. Proc. Am. Power Conf., 19, 729-735; disc. 735-740 (1957).

Aluminum tubes were found satisfactory for use in condensers under conditions at Oak Creek Power Plant. In Units 1 and 2, tubed with arsenical Admiralty tubes in steel tube sheets, trial tubes were internally Alclad while others were Alclad inside and outside and had longitudinal welded seam. Based on trial results and economic reasons, Unit 3 had aluminum alloy tubes exclusively. Steam side was provided with stainless steel shields in areas where Units 1 and 2 had experienced erosion on Admiralty tubes. Several bottom rows were plugged due to steam side erosion. These tubes suffered impingement from condensate from extraction header flashing due to inadequate baffling. Water side erosion was minor (less than 0.001 inch during 7 months). Sludge accumulations have been small and no build-up has occurred in controlled-circulation orifices. Higher concentrations of aluminum are found in boiler water and in preboiler cycle upon starting up new unit as compared to those existing after substantial period of operation. Aluminum wastage is not influenced by morpholine concentrations up to 5.8 ppm. Ammonia due to morpholine and other sources tends to concentrate in steam jet drains. Tables give typical analysis of Lake Michigan water and data for morpholine effect on aluminum pickup.—INCO. 17051

8.2.2, 8.4.5, 8.9.1, 7.7

Where Will Electric Power Come

From in Space Ships? J. Gustavson. Aviation Age, **29**, No. 4, 186-189 (1958) April.

Discusses chemical batteries, atomic batteries and thermo couples as 3 most likely sources for power in space vehicles. Among chemical cells, nickel-cadmium and silver-zinc types appear best. Nickel-cadmium battery is very rugged and withstands high accelerations. It is a secondary cell and also has excellent temperature characteristics. Draw-back is its high weight-watts ratio (shown in graph). Among atomic cells, contact potential and solid dielectric types depend upon radioactive energy source; solar cells build up potential by converting photons of sunlight into energy. Most common solar cell consists of thin silicon disk with invisible boron coating on side that faces sun. Thermocouples are best for outer solar system. Most promising couple is made of lead sulfide with zinc-antimony alloy.—INCO.   16927

8.8 Group 8

8.8.5, 3.7.3, 8.4.3, 6.2.4

Casting Weldments in a Petroleum Refinery. J. Bland, C. B. Parrish and R. C. Wheeler. Paper before Joint Meeting Am. Soc. Mech. Engrs. Metals Eng. Division Conference and Am. Welding Soc. Annual Spring Meeting., St. Louis, April 14-18, 1958. Welding J., **37**, No. 8, 789-798 (1958) Aug.

Several typical applications of casting weldments in a petroleum refinery are described. Results of some limited studies of weldability characteristics of low and intermediate chromium-molybdenum alloy steel castings are discussed. Castings which meet specification requirements for chemistry and tensile properties, in addition to being virtually free from casting defects, are satisfactory components for piping and auxiliary equipment. Maintenance and repair problems associated with casting weldments are reviewed and examples discussed. These include components of chromium-molybdenum steel, stainless steel, brass, bronze, and aluminum-bronze.—INCO.   17313

8.8.5, 3.7.4, 6.3.6

The Effect of Particle Size on the Sintering of Copper Powder. A. Duffield and P. Grootenhuis. J. Inst. Metals, **87**, Pt. 2, 33-41 (1958) October.

Loose copper powders of spherical form were sintered under vacuum at 650 C for 10 hr. to form a porous material. Effects of varying particle size and size distribution within each batch of powder upon properties after sintering were studied. Electrical conductivity was measured to determine degree of bonding throughout entire specimen. Measurement of tensile strength showed up the weakest section. Electrical conductivity, being an "average" property, was found to be independent of particle-size distribution but to vary with the mean size, even for specimens of equal densities. Tensile strength depended markedly upon size distribution, greatest strength of porous material being obtained with powder of small size and very limited size distribution. It was deduced from analysis that weakness of sintered porous material compared with solids is due to geometric factors only and not to any inferiority of the actual bond material. Graphs, diagrams, tables. —INCO.   17245

8.8.5, 5.3.4, 8.9.2, 4.2.1

Finishing Die Castings. E. E. Carlson. Hanson-Van Winkle-Munning Co. Precision Metal Molding, **16**, No. 8, 39-41 (1958) August.

Probably ⅓ of die castings made are used in automotive trim where they are copper, nickel and chromium plated, and it is severe outdoor exposure due to salts used in winter on roads and changes in humidity and exposure conditions that have led to poor corrosion resistance on many plated die castings. Factors involved in obtaining good corrosion resistant plating are casting quality, cold shot, solder spots, blisters and surface finishing. Latest development in improving corrosion resistance of die castings used for outdoor exposure is to apply what is known as duplex nickel deposits over the copper. Duplex nickel deposits improve corrosion properties of over-all plating. It was found that corrosion resistance is decidedly improved over a fully bright single nickel plate which would be equivalent tin thickness to thickness of duplex coating. Photomicrographs.—INCO.   17289

8.9 Group 9

8.9.5

Ocean-Racing Auxiliary Ketch Kamalii. J. Joseph. Diesel Progress, **24**, No. 10, 40-41 (1958) Oct.

Description of yacht Kamalii. Fuel tanks are made of Monel. Propellers are of manganese bronze. Fresh water is supplied by an electric-driven pressure pump working with a 15 gal. Monel pressure tank—615 gal. of fresh water are carried in 3 Monel tanks located beneath forward cabin floor. Kamalii's steering system consists of a Monel quadrant attached to a 2¾ in. bronze rudder stock. To this are tied stainless steel tiller ropes. Photos.—INCO. 17331

8.9.5, 6.4.2

MV Sumter—First All-Aluminum Tug. C. W. Leveau. Marine Eng./Log, **63**, No. 8, 73-75 (1958) July.

The 55-ft. 460 hp, all welded boat is designed for use in the bayous and marshlands oil fields of Southern Louisiana. Its shallow, 4½ ft draft made possible by its aluminum construction will permit its use in waters too shallow for conventional tugs of the same size. It was constructed of corrosion-resistant, high-strength weldable alloys 5053 and 5086, developed by Kaiser Aluminum. The Sumter offers, in addition to its shallow draft, the advantages of long life relatively free of maintenance and economy of operation. Because of its aluminum construction the boat is expected to experience less vibration and noise, reducing equipment wear and crew fatigue. The only non-aluminum parts in the boat are those in the engine plus the propeller and propeller shaft which are made of bronze. All bolts, set screws and other fastening devices are of stainless steel. Photos.—INCO.   17117

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TECHNICAL PAPERS SCHEDULED FOR FEBRUARY PUBLICATION

Oxidation of Metals by Carbon Dioxide at Temperatures of 1100 F to 1740 F and Pressures of 100 to 200 psi, by J. C. Bokros and W. P. Wallace

Use of High Silicon Cast Iron for Anodes—Fourth Interim Report of NACE Technical Unit Committee T-2B on Anodes for Impressed Current.

A Proposed Standardized Static Laboratory Screening Test for Materials to Be Used as Inhibitors in Sour Oil and Gas Wells—Report of NACE Technical Unit Committee T-1K on Inhibitors for Oil and Gas Wells.

Corrosion Behavior of High Purity Vanadium, by David Schlain, Charles B. Kenahan and Walter L. Acherman

Corrosion Testing of Two Zirconium Alloys, by Stanley Kass

Source of Underground Corrosion Potentials, by K. G. Compton

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Qualification of Inconel for Nuclear Power Plant Applications, by H. R. Copson and W. E. Berry

A Laboratory Paint Test Program*

By R. E. GACKENBACH

Introduction

INDUSTRIAL ENVIRONMENTS are varied; even within a given plant, there can be several dissimilar exposures. Many different types of paint must be used because no one paint is acceptable for all environments. Consequently, the services of a specialist are needed.

Neither manufacturer nor user alone can determine the best paint for a given application; therefore a test program is needed. Because each process industry has its own peculiarities, each test program must be formulated to meet individual requirements. The procedure developed by American Cyanamid Company was tailored specifically for conditions within its organization and may or may not be applicable for other groups. However, it has been an aid in paint selection and has minimized the guesswork normally present in an over-all painting program.

Before a paint test program can be drawn up, one must decide what properties are required in a paint system. This was done after consultation with paint manufacturers, paint users and maintenance and engineering personnel in the company. Desirable qualities were organized into a list titled "Performance Requirements" covering primers and chemical resistant finishes. Performance requirements for primers are listed in Table 1.

In testing, one and two coats of primer were evaluated. A generically similar primer of known performance was tested with the sample primers and was used for comparison. All testing, unless otherwise indicated, was performed at 77 F ±5 F and a relative humidity below 65 percent. Paints were mixed in accordance with manufacturers' instructions; no thinning was done unless specifically called for by the paint maker. The evaluation is based on a system of 10 numbers. A rating of 10 indicates superior qualities, zero signifies very poor features and the numbers 9 to 1 designate various stages between the extremes.

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At the beginning of the test program, panels were made by the maintenance department from any type of steel sheet available. The panels contained all types of surface irregularities such as mill scale, rust, scratches and nicks which interfered with the paint film and produced erratic results. Therefore, a panel of uniform surface characteristics (new 3-inch by 6-inch carbon steel) were purchased. A ¼-inch hole was drilled in top center of each panel. Panels were then stamped in the upper right-hand corner with a code number identifying the primer being tested. Panels were degreased with a commercial solvent, dried and placed in an oven or dessicator until ready for use.

Brush Application

An attempt was made to apply paints in a manner closely approximating that used by plant painters. Brush application was most widely used for priming be-

Abstract

A laboratory paint test program is described as a method of screening paints to select the specific item that will give the degree of protection needed for specific applications. Benefits and pitfalls of such a program are outlined. Paints that fail in the laboratory will probably fail in the field. Those that show promise in the lab must be field tested to determine final suitability.   2.3.7

cause it forced the paint into all the surface imperfections and crevices. Spray application had a tendency to bridge gaps and crevices and was used only on large exposed plane surfaces. A single brush coat of the primer under test was applied to both sides of a steel panel. For convenience in painting, the top ½-inch was not coated.

After 24 hours, a second primer coat was applied to the right-hand half of the panel. During both applications, the relative ease of brushing was compared with descriptions given in Table 2. Special attention was given to flow marks, laps, run-out and webbing. The ideal primer should brush on with smooth, easy strokes and should not run out or web; flow marks should readily dissipate and leave a uniform coat. Only a small percentage of primers proved difficult to brush out.

Simultaneously, the time of application was recorded. After 15, 30, 45 and 60 minutes the paint film surface was checked for degree of dryness. At the end of one hour, the primer was examined hourly. In drying, time was judged by touching with the finger and noting the tackiness. The length of time a brush coat required to dry tack-free on a steel surface was converted to a number as given in Table 3. A primer that dried tack-free in less than 30 minutes usually became difficult to apply and could not be brushed out. If the drying time exceeded four hours, the film was susceptible to damage by fumes and picked up large amounts of dust, dirt and moisture. For maximum protection, re-coating should be possible after eight hours although 24 hours is normally allowed.

Dry film thickness measurements were taken of each coat by instrument after

TABLE 1—Performance Requirements for Primers

1. Use	Interior and exterior structural shapes, piping and equipment
2. Surfaces	Steel-Carbon and low alloy
3. Surface preparation	Sandblasting, power brushing and wire brushing
4. Method of application	Brush, spray, and roller
5. Compatibility with other paints	Must be compatible with oil, rubber and synthetic base finishes
6. Normal allowable temperature limit for application	40-160 F
7. Dry film thickness	1.5 mils/coat minimum

8. Normal drying time—
    To touch (Tack free)
    To recoat
	½— 4 hours
	8—24 hours

9. Upper temperature limit in service	250 F
10. Chemical resistance	Good to excellent

TABLE 2—Brush Application

```
10  Superior flow quality
 9  Smooth-easy flow
 8  Smooth to moderate flow
 7  Moderate flow
 6  Poor flow
 5  Difficult to brush
 4  Runs
 3  Begins to web
 2  Webs
 1  Any combination of 2-3-4-5
 0  Cannot apply
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TABLE 3—Drying Time

```
10  30—45 minutes
 9  45—60 minutes
 8  1—2 hours
 7  2—3 hours
 6  3—4 hours or 15—30 minutes (S or F)
 5  4—8 hours or less than 15 minutes (S or F)
 4  8—12 hours
 3  12—16 hours
 2  16—20 hours
 1  20—24 hours
 0  Over 24 hours
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TABLE 4—Chemical Resistance and Water Bath

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10  Perfect—no change
 9  Stain or slight discoloration
 8  Discoloration
 7  Pin blistering—few
 6  Pin blistering—moderate
 5  Pin blistering—many; Alligrating—slight;
      Blistering—few
 4  Alligrating—moderate; Blistering—moderate
 3  Alligrating—bad; Blistering—many
 2  Softening
 1  Partial dissolution of film
 0  Dissolution of film
```

TABLE 5—Scratch Evaluation After Stripping

```
10  Perfect—no change.

 9  Very little change—slight deepening of scratch
      but no spreading of width

 8  Very little change—slight deepening of scratch
      with slight spreading of width

 7  Same as 8 but with some surface blemish

 6  Widening of scratch to 1/16" max. on either side
      with deepening of scratch and some blemish

 5  Widening of scratch to 1/8" max. on either side
      with deepening of scratch and some blemish,
      or, widening of scratch to 1/16" max. on either
      side with deepening of scratch and medium
      blemish

 4  Widening of scratch to 1/4" max. on either side
      with some surface blemish, or, widening of
      scratch to 1/8" max. on either side with deepen-
      ing of scratch and medium blemish

 3  Widening of scratch to 1/2" max. on either side
      with spotty breakdown of edges or widening
      of scratch to 1/4" max. on either side with
      deepening of scratch and medium blemish

 2  Widening of scratch over 1/2" max. on either side
      with moderate breakdown of edges

 1  Severe edge breakdown with underfilm corrosion

 0  Complete failure
```

24 hours' drying time. Ten readings for each coat (five on each side of the panel) were averaged. In the process industries, it is standard practice to specify a 3-coat system with a 5.0-mil average thickness and a 4.5-mil minimum thickness. Each coat should carry its share of the load; thus, the minimum primer thickness should be 1.5 mils.

In the laboratory, there is a tendency to apply the paint too thick or too thin. This can be overcome with practice. It is important that the paint film build used on the test panels be the same as that achieved by plant painters. A difference of one or two tenths of a mil is not critical and is the normal variance found in field practice. Laboratory film build determinations made in these tests to find the range of thickness (low, medium, high) are not absolute values because of the many inherent variables such as panel size, brush size and painter technique.

Accelerated Test

Test panels were cured one week before immersion in the water bath test. This test is an accelerated means of determining permeability and general breakdown of paint film. The water bath consisted of a stainless steel pan through which tap water flowed at a slow but constant rate. Flowing water was used to prevent stagnation of the water, build up of corrosion products and loss of water level. Bath temperature was constant at 105 F ±5 F.

Before immersion, the coated panels were scratched to bare steel on one side with a pen knife. The scratch in the one primer coat extended from the upper left corner to the middle of the bottom; that in the two primer coats extended from the upper right to the middle of the bottom, thus forming a V scratch. The scratch was made to ⅛-inch from the end of the panel so that the coating was not damaged and edge failure was not accelerated. The bottom half of the scratched panels was suspended in the water bath by a glass rod for 25 days. After removal, degree of failure was rated numerically by the description shown in Table 4. Special attention was given to blistering, alligatoring, adhesion and general breakdown.

After the water bath evaluations have been made, the bottom 3½ inches of

each test panel was solvent stripped. The scratch and the immediate vicinity were examined to determine effectiveness of the inhibited primer. Minor changes in the width and/or depth of the scratch were tolerable and indicated the primer was effective. Severe corrosion, underfilm attack and edge breakdown were not desirable. Some surface blemish caused by paint film permeability was allowed. The descriptions of the various ratings are given in Table 5.

The water bath was chosen for its accessibility, compactness and ease of operation. Experience has indicated that data obtained from this test was almost identical to that procured with standard salt spray test. There is little relationship between the salt spray test and chemical resistance in other environments. The same holds true for the water bath test. The water bath data were not always identical with data obtained from the salt spray test but were of the same order of magnitude.

Before the water bath was adopted as the standard, two identical sets of test panels were painted and aged. One set was run in the salt spray; the other in the water bath. After exposure, each set was rated individually in order of performance. When the two lists were compared, they were identical except for 3 panels which were out of order by no more than one number.

Chemical Resistance of Primers

Primers are essentially bonding agents, formulated to provide excellent adhesion to the substrate and a base to which the top coats can be applied. Primers generally contain some rust inhibitive pigments and, thus, provide some protection against atmospheric and chemical attack. A primer with good chemical resistance will enhance a system's over-all protective value. A primer with poor chemical resistance cannot be relied upon to furnish protection until the top coat is applied. Often such a primer will cause premature failure of the system.

In construction or maintenance work, the primed structure and equipment are exposed to moisture and chemical fumes while awaiting a top coating. Therefore, each primer must have some chemical resistance.

New ½-inch round bar stock of SAE

1020 steel was cut into 4-inch lengths for these tests. Ends of each rod were rounded and a ⅛-inch hole drilled in one end. The rods were free of mill scale. The primer was applied by dipping. The test bar was slowly lifted automatically from the paint; the rate of pull-out was adjusted so that there was no sagging or running. After aging for 7 days, the dry film thickness was measured. The coated specimens, inserted in a rubber or cork stopper, were half immersed in a glass
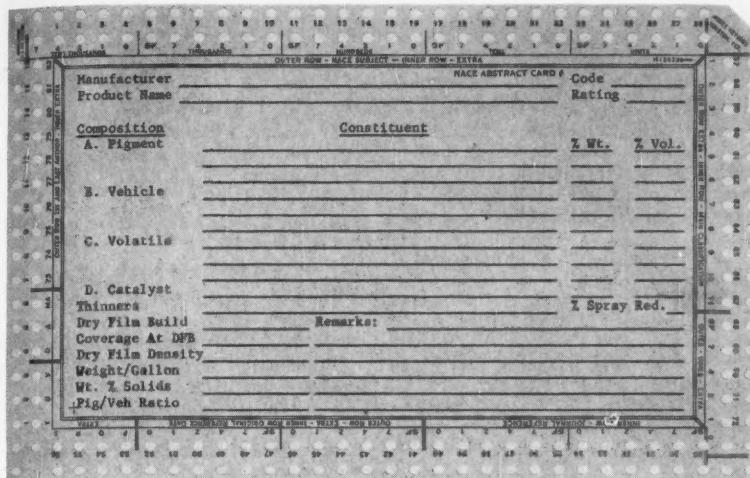
Figure 1—Punch card used for paint test data, front side.

Figure 2—Back side of punch card for additional paint test data.

TABLE 6—Performance Requirements for Finishes

1. Use..	Interior and exterior structural shapes, piping and equipment
2. Surfaces...................................	Steel—Carbon and low alloy
3. Colors....................................	Medium and dark shades
4. Gloss (ASTM D523)........................	2—30 maximum
5. Method of Application.....................	Brush, spray, roller
6. Compatibility with other paints...........	Must go over primers which are recommended by the manufacturer and must be compatible with the old paint film
7. Normal allowable temperature limit for application...............................	40—160 F
8. Dry film thickness........................	1.5 mils/coat minimum
9. Normal drying time To touch (tack free)........................ To recoat................................	½—4 hours 8—24 hours
10. Upper temperature limit in service...........	250 F
11. Chemical resistance-splashes and spills........	Excellent

TABLE 7—Final Evaluation

Rating	Application	Drying Time	Water Bath	Scratch	Resistance
A....................	7 minimum	7 minimum	5 minimum	5 minimum	Excellent
B....................	6 minimum	6 minimum	4 minimum	4 minimum	Good
C....................	5 or less	5 or less	3 or less	3 or less	Poor

bottle containing the test solutions. The primers are tested in 11 solutions: 10 percent sulfuric, 10 percent nitric, 10 percent hydrochloric, 10 percent acetic, 10 percent sodium hydroxide, 50 percent sodium hydroxide, 10 percent sodium carbonate, benzene, methanol, carbon tetrachloride and methylethyl ketone.

Sulfuric acid tested the coating's resistance to a non-oxidizing acid. Because of its volatility, hydrochloric acid determined the coating's impermeability and its resistance to a non-oxidizing acid. The resistance to an oxidizing media was checked by nitric acid. Acetic acid established the degree of impermeability and resistance to organic materials. The alkalies established chemical resistance and degree of saponification. The solvents defined the coating's resistance to various organic groups. Normal exposure was 24

hours. However, if no reaction occurred in this time, the specimens were exposed up to 7 days with examinations on the 4th and 7th days for discoloration, blistering, alligatoring, softening and dissolution of the paint film. Table 4 was used in rating the specimens. This test determined the chemical service in which each paint could be used.

Chemical Resistance of Finish Coats

The primer is only one part of the system. A top coat or two are required to furnish optimum chemical resistance against a corrosive environment. Performance requirements for chemical resistant finishes are given in Table 6.

The testing procedures and rating charts used to evaluate proprietary paints classed as chemical resistant finishes were the same as those for testing primers. An
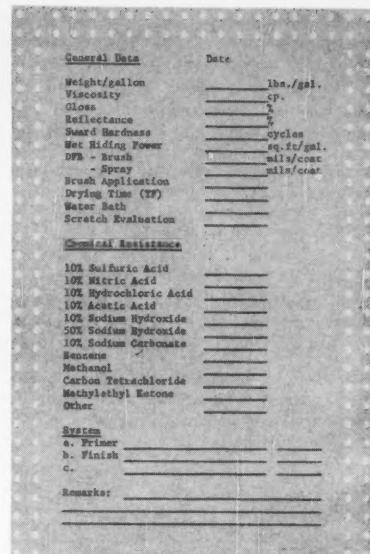
exception is the use of one diagonal scratch per panel. An effort was made to test and use complete systems as recommended and supplied by the paint manufacturer. Occasionally, mixed systems were tested, but these were kept to a minimum. The testing of chemical resistant finishes was conducted simultaneously with the primers.

In the water bath testing of finish paints, only one top coat was applied to the primer. This decreased the amount of work, cut the time to failure and quickly eliminated marginal systems. It is believed that what one top coat can do, two can do better. Thus, if one primer coat and one finish coat perform in an excellent manner, the second top coat can be expected to improve the system's effectiveness, as shown by field test data. Chemical resistance data was procured from rods containing only the finish or top coat.

This test procedure has been developed over a period of years, having undergone many revisions and modifications. The program has been designed so that different persons can do the testing at different times and still obtain reproducible results. The best systems are under constant scrutiny. They are re-tested to check original data and to assure that the quality has been maintained. Some systems re-tested 10 or more times by various persons have shown surprisingly similar results. Once a person is familiar with the rating system, ratings by two persons will not differ by more than one number. All test data were recorded on paint data test sheets and transferred to punch cards, shown in Figures 1 and 2.

Final evaluation of the coatings system was based on results of the individual tests. Each test in the procedure was considered important and was included to assess certain paint character-

istics. Thus, each test carried equal weight. Poor showing in one test could lower the over-all rating of the system.

The final evaluation chart, Table 7, was based on the outcome of tests on 250 systems including about 20 percent repeats. Panels were individually rated and the results of each separate test were tabulated according to frequency. About 25 percent of the systems checked to date fall in Rating A, another 50 percent in Rating B and the last 25 percent in Rating C.

To meet minimum requirements set in the performance requirements, the paint system must fulfill the following six points:

1. Rated 6 or better on application. A paint that is difficult to apply might be handled in a haphazard manner by painters, thus leading to premature failure.

2. Rated 6 or better in drying time. If the paint dries too fast, it leads to poor application. If it dries too slow, the paint film picks up dust and/or moisture from chemical atmospheres. These contaminants can easily lead to early paint film failure.

3. High enough in solids content to have a minimum dry film thickness of 1.5 mils per coat. Less than this makes it difficult to attain a 5-mil thickness in a three-coat system consisting of one primer coat and two finish coats.

4. Rated 4 or better in the water bath test. Lower ratings indicate excessive porosity, poor adhesion and general inadequacy of the film.

5. Rated 4 or better on scratch evaluation. Lower ratings indicate excessive porosity, breakdown of film, underfilm corrosion and/or a non-inhibitive primer.

6. Rated good or better in chemical resistance. Poor chemical resistance signifies unsatisfactory performance in plant environments. Resistance to the various chemical groups, acids, alkalies and solvents is individually considered and evaluated.

After testing, the paint rating for individual tests was converted to a final rating letter: A, B or C. A denoted an excellent system worthy of further testing for application in the most severe services; B designated a good system which could be used in milder environments; C signified a system that did not meet minimum requirements and was unsuitable for application in a chemical atmosphere.

Conclusions

A laboratory test program is a screening process. It offers convenient, low cost and quick results but does not indicate which paint is most suitable for a given application. Indeed, the results are just the opposite: The program indicates which paint is not suitable. Therefore, the most promising systems must be tested in the field or plant.

DISCUSSION

Question by Lt. Col. Serge Tonetti, U. S. Army Chemical Corps, Sheffield, Alabama:

The labor application cost of brushing a primer is several times the labor cost of spraying. Is your strong preference for brushing primers based on theoretical reasons or actual field evaluation?

Reply by R. E. Gackenbach:

Preference for the brushing of prime coats is based on actual experience in our chemical plants.

Question by Kenneth Tator, Coraopolis, Pennsylvania:

Do you test paints in single coats or systems?

Reply by R. E. Gackenbach:

Primers are tested alone and in combination with suitable top coats. However, the primer and top coat must be a system recommended by the paint manufacturer. The primer of one company is not tested with a top coat of another company.

Question by E. G. Brink, American Viscose Corp., Marcus Hook, Penn.:

Have you obtained good correlation between film thickness measurements made in the laboratory and those obtained in the field?

Reply by R. E. Gackenbach:

There is no real correlation. The film build data gathered from this test is only a guide. Paints that form thin films in the lab generally form thin films in the field; the same holds true for the heavier build paints.

Testing of Coal Tar Coatings (4) – Surface Preparation And Atmospheric Exposure*

By W. F. FAIR, JR.

Introduction

ATMOSPHERIC EXPOSURE tests in an environment of known pronounced corrosivity were conducted to determine whether non-bituminous inhibitory pigmented primers should be specified for all applications of coal tar protective coating systems.

Coal tar technologists have maintained that such primers would contribute little to the life of a coal tar protective system because cold applied coal tar coatings are self-priming, impermeable to water and usually heavily applied. Paint chemists have advised that non-bituminous primers should be specified as good practice because such primers should give at least some degree of longer life to the coating system and should help minimize edge corrosion.

Materials Used in Tests

Various primers were provided by technologists experienced in non-bituminous protective paint systems. The cold applied coal tar barrier and top coats used in different areas have previously been described in an earlier paper in this series.[1] Briefly, these coatings have been described as light duty (Class 1), moderate duty (Class 2), heavy duty (Class 3), pitch emulsion (Class 4) and light duty, potable, (Class 5).

Most primers cannot be used with coal tar coatings because of the high solvency properties of coal tar solvent naphtha which usually must be used to keep the solid coal tar constituents in suspension. Such aromatic solvents usually act as commercial paint removers when applied over conventional oil base inhibitory pigmented primers.

Exceptions to the above are the so-called wash primers (or metal conditioners) and solvent-resistant red lead epoxy primers. Reportedly, Class 4 pitch emulsions can be used safely in combination with some pigmented primers, but it is always advisable to make patch tests for each primer and coating pair under consideration.

Surfaces to be used for this test were selected in a coke plant at Kearny, New Jersey. This location's atmosphere is very corrosive because of fumes, sharp winter-to-summer and day-to-night temperature changes, coke breeze and particularly because of tidal river water condensation used in the plant coke quencher, which distributes salt-laden moisture over all exposed surfaces.

About the Author

W. F. FAIR, JR., is eastern technical representative for the Tar Products Division of Koppers Company, Inc., Verona, Pa. He has an AB from Harvard College and MS and PhD in chemistry from Columbia University. He has been president (1956) and vice president of NACE, chairman of the Metropolitan New York Section and member of the NACE Board of Directors. He is also a member of American Chemical Society, American Institute of Chemists, ASTM and Society of Rheology.

Actifier Tower Coating

An actifier tower was the first structure coated. Coating systems used on this 54-foot high, 20-foot diameter welded steel tower were applied on panels 26.9 inches wide and 41-foot high, leaving a 12-foot, 9-inch high section at the top of the tank. The lower 20-foot tower section was sandblasted and permitted to rust for a minimum of four days before coating.

Just before application of the scheduled priming coat, the upper portion of each panel was sandblasted and the lower portion, which had been permitted to rust, was power wire-brushed. This rust was very soft and readily removed by wire brushing. The surface thus obtained was almost comparable to a freshly sandblasted area and cannot be

TABLE 1—Actifier Tower

Sections	Primer Type	Barrier Coat*
1 & 15	Tar Cutback	Tar Emulsion
2 & 16	WP-1	Tar Emulsion
3 & 17	WP-1	Heavy Duty Cutback
4 & 18	Wash Primer (a)	Heavy Duty Cutback
5 & 19	Wash Primer (b)	Heavy Duty Cutback
6 & 20	Red Pb Epoxy	Heavy Duty Cutback
7 & 21	Red Pb Epoxy	Heavy Duty Cutback
8 & 22	Phenolic	Heavy Duty Cutback
9 & 23	Same As Barrier	Heavy Duty Cutback
10 & 24	None	Heavy Duty Cutback
11 & 25	None	Moderate Duty Cutback
12 & 26	Same As Barrier	Moderate Duty Cutback
13 & 27	Red Pb Epoxy	Moderate Duty Cutback
14 & 28	Red Pb Epoxy	Tar Emulsion

* All topcoats were emulsions.

Abstract

Discusses necessity of specifying non-bituminous inhibitory pigmented primers for all applications of coal tar protective coating systems. Describes tests in which selected primers and coal tar coatings were applied to coke plant areas subject to high atmospheric corrosivity. All systems applied to wire-brushed surfaces, primed or unprimed, failed within one year. The same systems on sandblasted surfaces, with and without primers, are still in satisfactory condition after five years' exposure in the same environment.

Coated panels have been exposed for about four years at Ingleside, Texas, Kure Beach, N. C., and Kearny, N. J. Contrary to expectation, some coatings are weathering faster at Ingleside than at Kearny. Some non-bituminous systems which have already failed in Texas are still in satisfactory condition in New Jersey. Results to date confirm the advisability of specifying coal tar pitch emulsion as the best top coat for coal tar protective coating systems subject to atmospheric exposure.   5.4.5

considered as typical of an old rusted surface after power wire-brushing.

Fourteen coating systems were applied in duplicate; each duplicate coated section was located 180 degrees around the tank perimeter from the partner system. Panels were numbered 1 through 28 around the tank; Areas 15 through 28 were duplicates of Areas 1 through 14.

Figure 1—Tight bond of coating to metal and lack of rusting in Section 1 of actifier tower. See Table 1 for coating used.

Figure 2—Lug bolt assembly at bottom of actifier tower Section 27 suffered loss of adhesion and edge corrosion. See Table 1 for coating used.

Figure 3—Loss of adhesion on manhole cover after one year's service in Section 28 of actifier tower. See Table 1 for coating used.

Figure 4—Manhole cover shown in Figure 3 after re-coating. Edge failures were wire-brushed, primed with a cut back coal tar primer and re-coated with two applications of pitch emulsion.
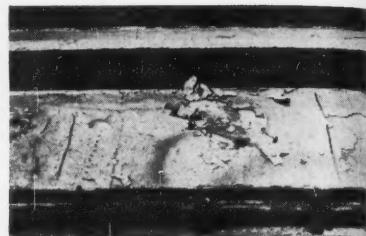
Figure 5—Coating failure on oxide box.

Each section boundary was marked at the tank bottom by a small piece of angle iron welded to the tank and at the top by notches cut into the bottom 6-inch reinforcing ring. Both the areas comprising the underside of the reinforcing ring and the 6-inch tower base flange were coated as part of the test areas. All coatings were brush-applied to the test panels except for the top coat of Class 4 Pitch Emulsion, which was spray-applied at the same time on all test panels.

The upper 12-feet, 9-inches of the side and the top of the tower were spray-coated separately after having been sandblasted.

Various combinations used on the different test sections are presented in condensed form in Table 1. These protective coating systems were applied as described above during April, 1953.

The coating systems were inspected semi-annually. Besides visual observation, incisions to bare metal were made in the coatings to determine whether any rusting had occurred and to learn if

the coating-to-metal bond was still satisfactory. In June of 1958, none of the systems on the actifier tower showed any signs of failure, except on a few edge areas described below.

Figure 1 shows the tight bond and lack of rusting in Section 1. Similar excellent

performance was found on Section 25 which had no primer and Section 27 which had a red lead epoxy primer. However, a lug, bolt and nut assembly near the bottom of Section 27 (Figure 2) showed definite loss of coating adhesion and edge corrosion after one year's exposure despite the original application of red lead epoxy primer. A similar condition (Figure 3) was found after one year on the edges of a manhole cover at the foot of Section 28, which also had been originally primed with a recommended red lead epoxy. In 1956, these edge failures were repaired by hand wire-brushing to remove lose coating, hand primed with a cut back coal tar primer and then recoated with two applications of pitch emulsion. Since this treatment, no further evidence of corrosion has been seen. Figure 4 shows the recoated manhole cover, two years later.

Oxide Box Tops

Near the actifier tower and thus subjected to the same extremely corrosive atmosphere, two oxide box tops were selected as suitable areas for additional

TABLE 2—Oxide Box Tops

Sections	Primer Type	Barrier Coat*
1	WP-1	Tar Emulsion
2	Tar Cutback	Tar Emulsion
3	WP-1	Moderate Duty Cutback
4	Wash Primer (a)	Heavy Duty Cutback
5	Wash Primer (b)	Heavy Duty Cutback
6	WP-1	Heavy Duty Cutback
7	Red Pb Epoxy	Heavy Duty Cutback
8	Phenolic	Heavy Duty Cutback
9	None	Moderate Duty Cutback
10	None	Heavy Duty Cutback
11	Red Pb Epoxy	Moderate Duty Cutback
12	Red Pb Epoxy	Tar Emulsion

* All topcoats were emulsions.

TABLE 3—Atmospheric Panel Tests

Panel	Primer	Barrier Coat	Class	Top Coat	Class
1A, B	None	Light Duty	1	Light Duty	1
2A, B	None	Light Duty	5	Light Duty	5
3A, B	None	Heavy Duty	3	Heavy Duty	3
4A, B	None	Heavy Duty	3	Pitch Emulsion	4
9A, B	None	Moderate Duty	2	Moderate Duty	2
10A, B	None	Moderate Duty	2	Pitch Emulsion	4
13A, B	Tar Cutback	Pitch Emulsion	4	Pitch Emulsion	4
14A, B	Tar Cutback	Pitch Emulsion	4	Epoxy Seal	White Paint
19A, B	Enamel Primer	Plasticized Enamel[2]	12[2]	Pitch Emulsion	4
20A, B	Enamel Primer	Semi-Plasticized Enamel[2]	9[2]	Pitch Emulsion	4
21A, B	Enamel Primer	Unplasticized Enamel[2]	5[2]	Pitch Emulsion	4
22A, B	Red Lead Alkyd	Pitch Emulsion	4	Pitch Emulsion	4
36A, B	WP-1	Pitch Emulsion	4	Pitch Emulsion	4
37A, B	Vinyl	Vinyl	(Proprietary)	Vinyl	(Proprietary)
39A, B	Red Lead Alkyd	Red Lead Alkyd	(Proprietary)	Proprietary	
40A, B	Red Lead Phenolic	Red Lead Phenolic	(Proprietary)	Proprietary	
41A, B	Red Lead Linseed	Red Lead Linseed	(Proprietary)	Proprietary	
42A, B	Neoprene	Neoprene		Neoprene	(Proprietary)
43A, B	WP-1	Black[a]	(Proprietary)	2 Coats, Black[a]	(Proprietary)
44A, B	WP-1	Special Primer[b]	(Proprietary)	2 Coats, Black[c]	(Proprietary)

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comparative testing. The 12 systems presented in Table 2 were applied separately to 12 horizontal areas on the two oxide box tops. One box top was first sandblasted, the other was carefully power wire-brushed. Coatings were applied in an identical manner to the two box tops by the same experienced crew. After one year, all systems on the wire brushed area had failed. Figure 5 shows a typical failure.

The identical systems were in satisfactory condition on the sandblasted box top after one year.

Priming or non-priming did not affect the behavior of these coal tar systems in this extremely corrosive environment.

Tops of these oxide boxes have to be removed as a unit every 18 to 24 months to replenish the spent oxide. Even during these frequent removals, none of the various systems on the sandblasted box top has lost adhesion to the metal. All systems exhibited satisfactory bond. No evidence of corrosion was found five years after application on the original sandblasted box top.

Atmospheric Exposure Panels

To supplement these exposure tests, panels coated with the above systems and with many other types of protective coating systems were exposed in different locations where the atmospheric corrosivity might exhibit considerable variation.

Steel panels (0.11 inch thick, 5.5 inches by 12 inches) were sandblasted on both sides and coated immediately. The backs of all panels received one coat of coal tar cut back primer and two coats of pitch emulsion (Class 4). The exposed surface was then coated with one of the systems listed in Table 3. For each location, panels were made in duplicate, the one designated "a" was scribed, and the "b" panel was unscribed.

One set of duplicate panels was exposed on a test rack at a tar refinery adjacent to the Kearny coke plant. Another set of panels was exposed at Kure Beach, North Carolina. A third set was exposed on the coast at Ingleside, Texas.

The panels were exposed on February 22, 1954, at Ingleside; June 2, 1954, at Kure Beach and September 28, 1954, at Kearny, New Jersey.

Some differences in behavior of different coatings were expected at these different locations. The Kearny panels were subjected to some corrosion conditions from the coke plant, depending upon wind direction and velocity. This is considered to be a marine-industrial atmosphere.

At Kure Beach, N. C., the racks were 800 feet from the ocean, with moderate to high temperatures and in a non-industrial atmosphere. At Ingleside, Texas, the panels were only a few feet from the water, exposed to high temperatures and intensive ultra violet radiation periodically in a non-industrial atmosphere.

Some of the results obtained to date were not anticipated. The systems listed in Table 3 exhibited different behaviors in New Jersey and in Texas. Generally, the results at Kure Beach were more
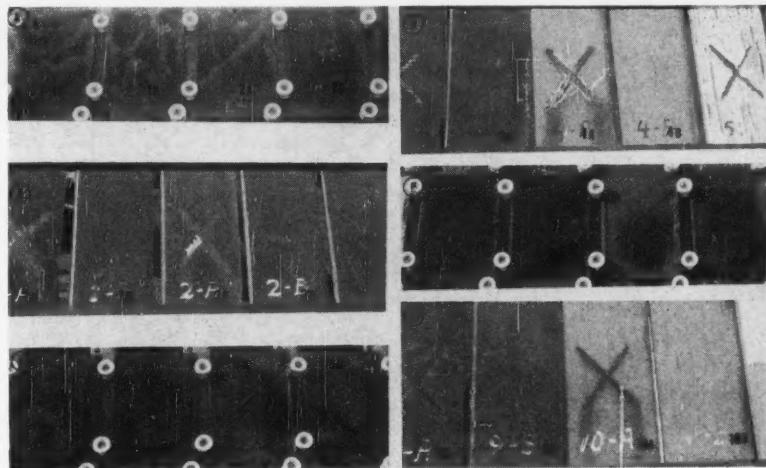
Figure 6—Test panels exposed four years in Texas and New Jersey. Part A: Condition of light duty coatings in Texas. Part B: Same coatings exposed in New Jersey. Parts C (Texas) and D (N.J.) are heavy duty coal tar coatings and for pitch emulsion over heavy duty coatings. Parts E (Texas) and F (N.J.) show comparative behavior of moderate duty coatings and pitch emulsion over moderate duty coatings. See Table 3 for coatings used on each panel.
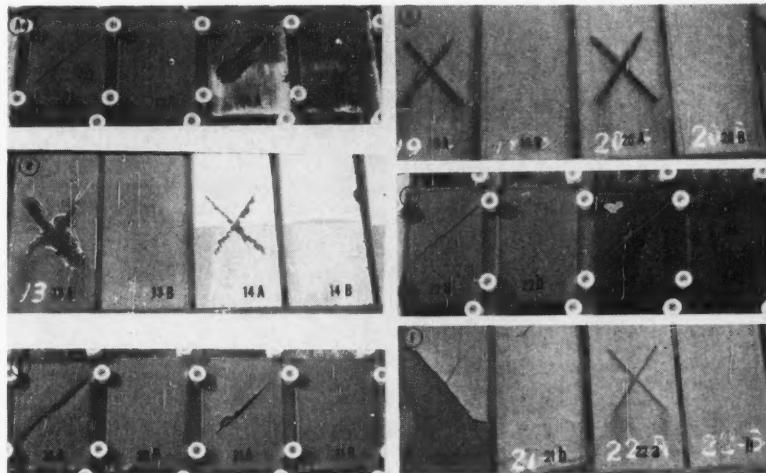
Figure 7—Atmospheric panel tests. Part A: Good performance of pitch emulsion over coal tar cut back and weathering effect on Texas panels. Part B: Better performance of same coatings in New Jersey exposure. Part C: Protection given by plasticized and unplasticized enamels during four-year Texas exposure. Part D: Protection of plasticized enamel by pitch emulsion and cracking of hard unplasticized enamel in northern exposure. Part E: Good performance of pitch emulsion over red lead alkyd primer in Texas exposure. Part F: Cracked unplasticized enamel and excellent condition of pitch emulsion over primer after four-year exposure in New Jersey. See Table 3 for coatings used on each panel.

similar to the results obtained to date in New Jersey.

Inspections were made and photographs taken at Kearny, N. J., in June, 1958; at Ingleside the photographs were taken in August, 1958.

Figure 6a (Texas) illustrates the condition of light duty coatings in August, 1958. Incipient failure had been observed within 3 years. Figure 6b shows the fairly good condition of the same coatings in Kearny in June, 1958.

Figures 6c and 6d show results in Texas and in New Jersey for heavy duty coal tar coatings and for pitch emulsion over a heavy duty coating. In both locations the panels were in good condition, but the Texas coatings ap-

peared to be surface weathering off faster than in New Jersey.

Similarly, Figures 6e (Texas) and 6f (N. J.) show the comparative behavior of moderate duty coatings and pitch emulsion over moderate duty coating.

Figure 7a (Texas) illustrates the good performance of pitch emulsion over a coal tar cut back and the weathering away of a white paint top coat applied to half a panel which had first received an epoxy sealer over the pitch emulsion coating. Figure 7b shows how much better the paint top coat is standing up in a northern climate.

Figure 7c shows the protection given to plasticized and unplasticized enamels[2] by a top coat of pitch emulsion, during
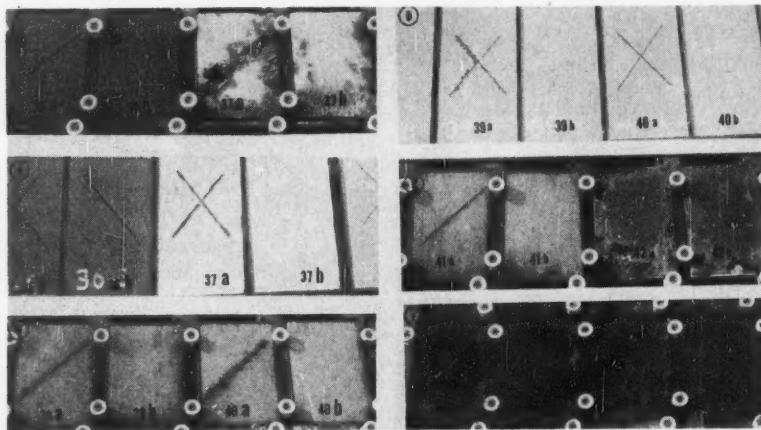
Figure 8—Comparative panel exposures. Part A: Good performance of pitch emulsion over wash primer and early failure of vinyl paint system in Texas exposure. Part B: Excellent condition of same two systems in New Jersey exposure. Part C (Texas) and Part D (New Jersey) show contrast of red lead alkyd system and red lead phenolic system. Part E shows condition of red lead linseed oil system a neoprene base paint which failed in Texas. Part F shows two other non-bituminous systems which failed early in Texas. See Table 3 for coatings used on each panel.

four years exposure in Texas. Figure 7d demonstrates that pitch emulsion protects plasticized enamel, but cannot prevent the cracking of hard unplasticized enamel in the North. Panels 21a and b both cracked severely in New Jersey during the first winter of exposure as expected.

Figure 7e (Texas) shows the good performance of pitch emulsion over a red lead alkyd primer (left). Figure 7f shows the above mentioned cracked unplasticized enamel, and the excellent condition of pitch emulsion over the same red lead alkyd primer after almost 4 years of exposure in New Jersey.

Figure 8a shows the good performance of pitch emulsion over wash primer and the early failure of a proprietary vinyl paint system in Texas. Figure 8b shows the excellent condition of the same two systems in New Jersey.

Another contrast can be seen in Figures 8c and 8d. A red lead alkyd system and

a red lead phenolic system, both with the same grey paint top coat, showed much less resistance to weathering in Texas than they are doing in New Jersey. Figure 8e shows the condition of a red lead linseed oil system with a grey paint top coat and a proprietary neoprene base paint which is failing badly with perforations in Texas. Duplicate panels are still in perfect condition at Kearny.

Figure 8f shows two other non-bituminous systems, both black pigmented materials over wash primer WP-1, exhibiting early failures in Texas. Duplicate panels, protected with the same commercially available compositions, are still exhibiting good resistance to the Kearny atmosphere.

Summary

Large scale test applications of various coal tar coating systems in a severely corrosive atmosphere demonstrate con-

clusively that good surface treatment such as by sandblasting is of utmost importance.

Used in combination with cold applied coal tar protective coating systems, pigmented inhibitory non-bituminous primers did not prevent failure in one year on power wire-brushed surfaces. The same systems, with and without primers, on sandblasted surfaces, are still in satisfactory condition after five years' exposure in a coke plant. It is not known whether the primers may ultimately contribute sufficiently to longer service life of these systems to be of economic value.

Atmospheric exposure tests of coated panels are being conducted at Ingleside, Texas, Kure Beach, N. C., and Kearny, N. J., through facilities provided by Sun Pipe Line Co., International Nickel Co., and Koppers Co., respectively.

After four years' exposure, earlier recommendations are confined to specify coal tar pitch emulsion as top coat for coal tar systems exposed to atmospheric corrosion. Also it appears that certain non-bituminous coating systems will fail rapidly at the Gulf location but will be satisfactory over the same period of exposure in a northern marine-industrial environment. Heavy duty coal tar systems are satisfactory at Ingleside after four years' exposure but are showing faster surface weathering of the top coating than is occurring in New Jersey in approximately the same length of time.

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2. NACE Technical Committee T-2G Report. *Corrosion*, 12, 75-76 (1956) January.

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Authors of technical papers on corrosion are invited to submit them for review without invitation to the Editor of Corrosion. Write for "Guide for the Preparation and Presentation of Papers" sent free on request to prospective authors.

Chemical Cleaning of Equipment
In Refineries and Petrochemical Plants*

By *LAMBERT N. KLINGE and JOHAN SELMAN*

Abstract

Discusses advantages of chemical cleaning in refineries and petrochemical plants over mechanical methods. Describes steps necessary in analyzing deposits to be removed, chemical agents used in cleaning, effects of these agents on construction materials and cleaning of equipment in situ. Includes cleaning of columns, coolers, condensers, heat exchangers, boilers and drums. Also includes discussion of potential corrosion difficulties encountered in chemical cleaning. Describes auxiliary equipment needed. Bibliography of 258 items on chemical cleaning and related subjects is given. 5.9.2

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Introduction

FOR CLEANING equipment in refineries and petrochemical plants, traditional mechanical methods gradually are being replaced by methods involving the use of chemicals. Chemical methods display the following advantages:

1. Chemical cleaning often can be done without dismantling the equipment, thus greatly reducing downtime and labor. This advantage is particularly apparent in cleaning columns and tubular goods.

2. Chemical cleaning is more thorough, reaching places which cannot be cleaned mechanically.

3. Chemical cleaning is more uniform, so that, in general, no particles of a deposit are left to form a nucleus for accumulation of new deposits.

4. Chemical cleaning avoids mechanical damage of metal surfaces, such as formation of sharp edges which can promote corrosion and formation of deposits.

In the United States, contractors have developed their own methods for chemical cleaning and can be called in to do cleaning jobs in refineries and petrochemical plants. In Europe, only a few firms specialize in this field; consequently, most companies with cleaning problems must develop their own techniques.

This article describes chemical cleaning as used in the Royal Dutch/Shell Group, the methods used being based on experience gained in refineries and plants belonging to this Group. The steps to be taken in chemical cleaning will be considered in some detail. Practical examples of cleaning refinery equipment will be given. Finally, the auxiliary equipment used in these operations will be described.

Sampling and Analysis of Deposits

In order to obtain data on the solubility of the deposit to be removed, samples are taken and examined in the laboratory. When a plant is shut down for clean-out and overhaul, there is often no time or opportunity to carry out complete analyses of deposits. It is therefore desirable to have available beforehand as many data as possible. By taking samples of deposits from each piece of equipment every time it is opened, and by having these samples examined in the laboratory, the necessary data will be obtained so that they are available when chemical cleaning starts. In the same

way data can be collected on the behavior of construction materials in the presence of cleaning agents.

When samples are taken the following must be kept in mind:

1. The sample must be representative of the fouling as a whole, which means that it has to be taken at various places and over the full depth of the deposit layer down to the bare metal.

2. When submitted to the laboratory, the sample must be accompanied by the necessary data: date, department, plant, equipment, material(s) of the equipment, number of the equipment, location where sample was taken, working temperature in the equipment, medium, and estimation of nature and degree of fouling.

Also the kind of examination required should be clearly stated, possibilities being complete analysis, determination of certain components, determination of solubility, etc. Sometimes advice is asked on the method of chemical cleaning to be applied.

The following method can be used for the laboratory investigation:

1. One hundred to three hundred grams of the sample are placed in a 20-mesh stainless steel basket and the tare weight is noted.

2. The basket is immersed in a suitable chemical cleaning solution at 30 to 40 C (85 to 105 F).

3. Sample is immersed in the test solution until definite conclusions can be drawn, with a minimum of one hour. Rates of reaction and decomposition should be observed periodically by removing the sample basket from the solution.

4. Upon completion of the immersion test, the sample is rinsed with hot or cold water for two minutes.

5. Sample is dried in an oven and weight loss is determined. Value obtained is an indication of the cleaning efficiency to be expected.

6. When it is evident or suspected that deposits have a high carbon content, a total destruction test is conducted by heating the dried sample in a crucible to 540 to 650 C (1000 to 1200 F).

From the results of this test, efficiency of the cleaning procedure can be established. However, the cleaning efficiency in actual practice may be higher due to agitation of the cleaning solution caused by high volume pumping. This leads to physical removal of the undissolved solids.

The circulation time of the cleaning solution is established by using "experience factors." For heat exchangers this factor is approximately five; for fractionating columns the factor is about nine, taking as a basis the cleaning time found in the laboratory.

Results of the laboratory examination can be summarized as showing (1) whether or not the deposit can be removed by chemical cleaning, (2) to what extent the removal will take place, (3) what type of cleaning agent is to be used, and (4) under what circumstances chemical cleaning can best be carried out.

Also, data obtained may indicate to what extent the formation of deposits can be reduced or prevented during future runs of the plant.

Identification of deposits by X-ray diffraction methods has found wide application in chemical cleaning practice.

Materials used in construction of the equipment to be cleaned determine and limit the choice of cleaning agents and the way in which these agents can be applied.

Because chemical cleaning can cause some corrosion of equipment, it is necessary to follow the advice of the corrosion engineer. Complete examination of the deposits should be made in consultation with the corrosion engineer. Furthermore, it is desirable that a special organization be set up to plan and carry out all chemical cleaning operations.

Types and Nature of Fouling

Deposits encountered in equipment of refineries and petrochemical plants can be divided into three main groups: inorganic deposits, organic deposits and mixtures of inorganic and organic deposits.

Inorganic Deposits

Inorganic deposits which may occur in cooling water circuits consist of a relatively small number of chemical compounds. If, for example, brackish cooling water is used in a system composed of steel lines, and including a condenser consisting of copper alloy tubes and tube sheets with cast iron channels, the groups of positive and negative ions which may be expected in the deposits are shown in Tables 1 and 2. A number of these compounds are soluble in water; others are hardly soluble or completely insoluble.

Organic Deposits

Organic deposits found in cooling water circuits are formed chiefly by biological growth (mussels, barnacles, algae, etc.). In some cases their presence can cause difficulties.

Of greater importance, however, are organic deposits encountered in the oil stream in cooling circuits, for example on the product side of tubulars. The number and diversity of these deposits are particularly great. Under the influence of heat, pressure and other conditions, a large quantity of compounds can be formed, varying from liquids which can be evaporated with relative ease to highly polymerized materials or decomposition products of a coke-like nature.

Identification of these deposits for the purpose of selecting a suitable cleaning agent is a laborious task. Cleaning solution choice is therefore determined experimentally; commonly, heavy duty alkaline materials, used in combination with detergents and/or wetting agents, are most effective in this application.

Mixtures of Inorganic and Organic Deposits

In refineries where sour crudes form the main base materials, deposits formed generally consist of organic compounds with inorganic constituents, principally iron sulfide, copper sulfide and some chlorides. The sulfides are corrosion products, formed because construction materials of the equipment react with hydrogen sulfide and other media containing sulfur. The chlorides originate from attack of the construction materials by hydrochloric acid, which in some cases is formed during processing.

Occurrence of fairly large quantities of sulfides, chlorides, etc., is no exception. In recent investigations 30 to 50 percent of inorganic material was found in mixed organic-inorganic deposits.

Chemical Cleaning Agents

In each separate case of chemical cleaning, choice of the most efficient cleaning agent and of the most favorable working conditions must be established experimentally. The limits set to this choice by the nature of the construction material of the equipment to be cleaned have already been mentioned. For economic reasons, selection of the most suitable cleaning agent is restricted further to a number of compounds which are kept in stock. However, these standard agents have been selected so that the maximum number of deposit types can be removed with the aid of the minimum number of cleaning agents.

Cleaning agents which can be considered for use are acids, sodium carbonate solutions, mixtures of sodium carbonate and sodium hydroxide solutions, hypochlorite solutions, neutralizing-passivating solutions, aromatic solvents, alkaline cresol solutions, and MIBC heavy ends.[1]

Acids

Sulfuric, nitric, phosphoric and hydrochloric acid are theoretically suitable for use in chemical cleaning; however, the first three acids have some properties which make their use in this application less attractive.

Sulfuric acid is dangerous to handle; moreover, on dilution of the acid considerable heat is released. Finally, the acid causes deposition of the insoluble calcium sulfate in cases where calcium salts are present in the deposits being removed.

Nitric acid is also dangerous to use. Furthermore, it gives off poisonous nitrous fumes and is difficult to inhibit.

Phosphoric acid presents hazards for personnel handling the product. This expensive acid possesses an undesirable property for chemical cleaning in that it can form insoluble calcium phosphates.

Compared to the other three acids, hydrochloric acid displays the following advantages: less dangerous to use, a cheap product, can be diluted easily and without danger, forms comparatively few insoluble salts and can be inhibited adequately, even at the relatively high temperature of 60 C (140 F).

For these reasons, 10 to 20 percent wt

[1] MIBC stands for methyl isobutyl carbinol. MIBC heavy ends, a product obtained in solvent plants, contains 10 percent MIBC, the remaining 90 percent being polyvalent alcohols.

hydrochloric acid is chosen most often as the cleaning agent for removing deposits from refinery equipment. A corrosion inhibitor, and in some cases a wetting agent, is added to this acid.

Corrosion inhibitors have to be evaluated in the laboratory, using a quickworking and simple apparatus which gives reproducible results. In this way the activity of the inhibitors can be determined under the circumstances prevailing during chemical cleaning.

A suitable inhibitor, when added in the usual dosage (from about 0.2 percent wt to 2 percent wt on undiluted acid), should reduce the corrosion rate to 1 to 5 percent of the rate caused by the uninhibited acid, when the inhibited acid is applied at temperatures below 40 C (104 F), and to 1 percent or lower when the acid is used at temperatures above 40 C. During chemical cleaning, care must be taken that the maximum allowable operating temperature of the inhibitor is not exceeded.

To increase the wetting effect, a small amount of a detergent can be added to hydrochloric acid. However, attention should be given to the compatibility of wetting agent and inhibitor, as the former may decrease the activity of the latter.

Hydrochloric acid can be used for chemical cleaning until the concentration has dropped to 6 percent wt. Then the acid is disposed of or brought to strength by addition of fresh acid. Iron content should never exceed 150 g Fe per litre of acid; ferric ion concentration should be kept below 0.4 percent wt.

Before chemical cleaning is started, action of the inhibited acid should be checked by means of test strips, the same temperature being maintained as will prevail during the actual cleaning operation.

When deposits containing sulfides are being dealt with, the poisonous gas hydrogen sulfide is formed as soon as the sulfides come in contact with hydrochloric acid. Moreover, during cleaning work the deposit layer may evolve volatile hydrocarbons and/or hydrogen, which may form an explosive mixture with air. Therefore, under all circumstances great care must be taken that there is adequate venting during chemical cleaning.

Of the sulfides mentioned in Table 2, iron sulfide dissolves most easily; copper sulfide most slowly. Calcium sulfate (gypsum) dissolves poorly in hydrochloric acid. When removing deposits which contain large quantities of this sulfate (for instance deposits occurring in boilers), it is advisable to apply a pretreatment with a hot sodium carbonate solution. The deposit becomes soaked with this solution so that in the treatment with hydrochloric acid which follows carbon dioxide is evolved, which breaks up the calcium sulfate layer.

Calcium sulfite occurs only sporadically in the deposits under consideration. If this salt is present, the development of sulfur dioxide formed by the action of hydrochloric acid may cause complications. Sulfur dioxide decomposes

TABLE 1—Ions Potentially Present in Inorganic Deposits

From Cooling Water		From Construction Materials
Positive ions (cations)	Negative ions (anions)	Positive ions (cations)
Ca	CO₃, HCO₃	Fe
Mg	SO₄	Cu
Na	Cl	Zn
K	S	
Fe	OH	
Mn	silicates	

TABLE 2—Compounds Potentially Present in Inorganic Deposits

Type of Compound	Elements
Carbonates	Ca-Mg-Fe-Mn-Cu-Zn
Basic carbonates	Ca-Mg-Fe-Mn-Cu-Zn
Sulfates	Ca
Silicates	Ca-Mg-Fe-Mn-Cu-Zn
Basic chlorides	Cu
Sulfides	Fe-Cu-Zn
Oxides	Mg-Fe-Mn-Cu-Zn
Hydroxides	Mg-Fe-Mn-Cu-Zn

the usual inhibitors, which can cause serious attack of plant equipment.

Sodium Carbonate Solutions

Under certain circumstances, use of a soda solution is required as a pre-treatment for further cleaning operations. In most cases for this purpose a 15 percent wt sodium carbonate solution is used to which a detergent has been added to increase the wetting power. The temperature is not to exceed 90 C (195 F).

Sodium Carbonate and Sodium Hydroxide Solutions

Under certain conditions, when the deposit to be removed contains more than 20 percent silicic acid or more than 60 percent calcium sulfate, a solution containing 50 percent wt sodium carbonate (soda) and 5 percent wt sodium hydroxide (caustic soda) is applied instead of the usual soda solution. In this case, too, the temperature should not be above 90 C.

Hypochlorite Solutions

Very good results have been obtained in cleaning the product side of heat exchangers (containing aluminum brass tubes) with an aqueous solution of sodium or potassium hypochlorite. The solution used contained 2 to 5 gram-ions of hypochlorite and 1 to 4 grams of sodium hydroxide per litre. The best temperature range for this type of cleaning operation is 40 to 65 C (105 to 150 F). The cleaning step is followed by water washing, a treatment with 5 percent wt inhibited hydrochloric acid and finally a second water wash.

Neutralizing-Passivating Solutions

After every cleaning operation involving the use of hydrochloric acid, the last traces of acid should be neutralized by a suitable neutralizing-passivating agent, for instance a trisodium phosphate/borax (or caustic soda) mixture.

Aromatic Solvents

Aromatic solvents possess a high solvent power for high molecular hydrocarbons, even when these compounds are mixed with asphaltenes. Two aromatic solvents which are often used for chemical cleaning are an Edeleanu extract with a boiling range of 110 to 160 C (230 to 320 F) and a gasoline fraction boiling from 100 to 160 C (212 to 320 F), obtained by distillation of an Edeleanu extract phase.

Alkaline Cresol Solutions

For deposits in which polymerized furfural derivatives are present, a solvent of the following composition can be successfully applied: 64 percent wt water, 15 percent wt industrial cresol, 20 percent wt sodium hydroxide, and 1 percent wt of an alkyl sulfate type detergent.

MIBC Heavy Ends

For deposits containing acid tar, MIBC heavy ends form a solvent of high cleaning power.

With the cleaning agents given above, used alone or in combination, the normal cases of deposit removal can be handled.
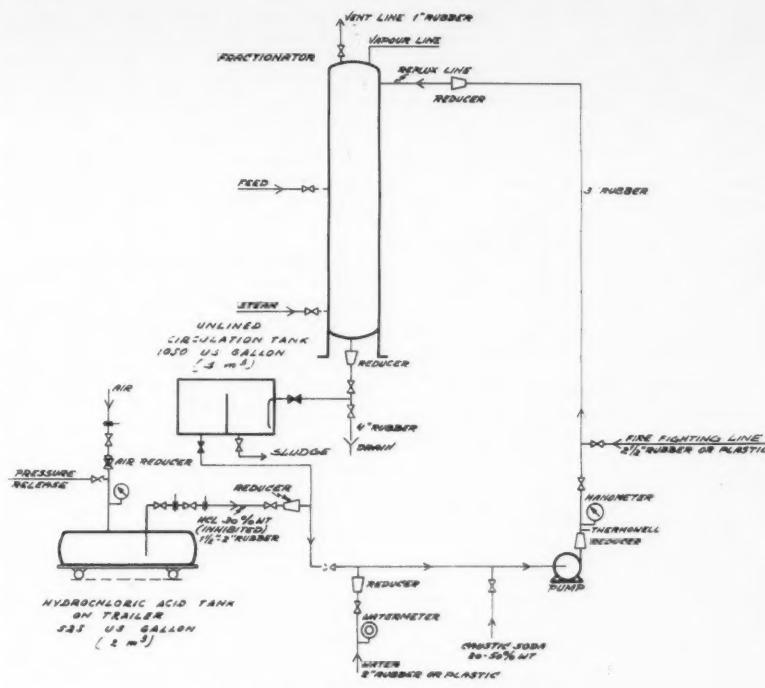
Figure 1—Standard line-up for cleaning refinery columns.

TABLE 3—Cleaning Agents and Construction Materials

	Steel	Cast Iron	Copper Alloys	Stainless Steel	Aluminum Alloys	Galvanized Material
A. Inhibited hydrochloric acid[1]	0	0	0	0[2]	x	x
B. Sodium carbonate solutions	0	0	0	0	x	x
C. Mixtures of soda and caustic soda solutions[3]	0	0	0	0	x	x
D. Hypochlorite solutions[4]	0	0	0	0	x	x
E. Neutralizing-passivating solutions	0	0	0	0	x	x
F. Aromatic solvents	0	0	0	0	0	0
G. Alkaline cresol solutions[3]	0	0	0	0	x	x
H. MIBC Heavy Ends	0	0	0	0	0	0

0 = No objection.
x = Use prohibited.
[1] Temperature not to exceed 60 C (140 F); lower maximum temperatures are required for certain inhibitors.
[2] 12%-14% chrome steel is liable to attack but the degree of corrosion is usually acceptable; preferably test strips should be exposed to the inhibited cleaning agent in the laboratory, to determine the effect of the inhibitor (see section on "Potential Corrosion Difficulties").
[3] In general, the temperature must not exceed 90 C (195 F).
[4] Maximum contact time two hours.

These agents should always be kept in stock. Also, it is desirable to have some extra storage available for mixing purposes, etc.

Effects of Cleaning Agents on Construction Materials

Table 3 shows which cleaning agents may be used for cleaning the common construction materials, applying a contact time of 24 hours.

Choice of Cleaning Method

Whether cleaning should be carried out *in situ* or in a central clean-out place depends on various factors. Cleaning *in situ* has the advantage that it is unnecessary to dismantle equipment to be cleaned. As the cleaning method is simple and quick, it can be done with a minimum loss of time and labor at minimum cost. These advantages become especially obvious in the cleaning of columns, bundles with fixed tube sheets and boilers. *In situ* cleaning is to be preferred when the deposits are reasonably soluble in one of the standard cleaning agents mentioned above, or possibly in a combination of two agents of different type. The latter case occurs, for instance, when a deposit consisting of heavy oil fractions containing inorganic material has to be removed. This can be done by combining the effects of a solvent type and an acid type cleaning agent.

If a deposit is difficult to dissolve or if the equipment to be cleaned has to be dismantled for some reason (for ex-

ample, removal of a tube bundle for inspection), this may justify cleaning in a central clean-out place where cleaning of small equipment often can be carried out more efficiently than in the plant, a number of baths containing different cleaning solutions being available.

Parts which can only be imperfectly cleaned in the plant or which may be damaged by cleaning, and parts of which the cleaning may be dangerous to personnel, also can best be handled in a central clean-out place.

Because in some refineries installation and use of such a clean-out place are still in the development stage, this article deals only with chemical cleaning *in situ*.

Cleaning of Equipment in Situ

It is assumed that the plant designers have taken into consideration the possibility of cleaning equipment by chemical methods, not only by providing adequate drainage systems but also by avoiding as far as possible pockets where liquids may become trapped.

The necessary nozzles for connecting pipelines and auxiliary equipment for chemical cleaning should be provided during the plant construction stage, so that actual connections for cleaning purposes can be made rapidly.

Special care should be taken of poisonous or explosive gases which can evolve during cleaning; ample ventilation must be provided and the gases vented to the flare.

Cleaning of Columns

The material required for cleaning columns should be on the spot and arranged in standard line-up before the plant or unit goes down. This standard line-up is shown in Figure 1.

After the column to be cleaned has been steamed out and flushed with water, it is placed at the disposal of the clean-out personnel. If necessary, the column is opened at a few places where deposits usually accumulate, such as the top feed inlet and the bottom trays, to obtain an estimate of the degree of fouling.

Hydrochloric acid of 30 to 35 percent wt concentration is supplied in transportable tanks; in storage and transport, good results have been obtained with rubber-lined tanks. Circulation of the cleaning agent takes place via the normal liquid route over the trays from top to bottom by means of the circulation pump.

It is recommended that the reboilers should not be included in the acid circuit. These should be cleaned separately; otherwise they can become clogged.

All lines not used during cleaning are blinded off. Instrument lines, level indicators, valves with highly finished surfaces, etc., are disconnected, the line entries into the column being plugged. Furthermore, it is essential that foolproof precautions be taken to prevent any leakage of foreign matter into refinery water systems. Finally, the column is connected to the standard line-up, after which cleaning can start.

A practical example of a column clean-out is given below. The column to be cleaned was 64½ feet high, had a diameter of 13½ feet and contained 16 trays.

1. **Introducing water into the column: 1 to 2 hours.** This is done over the top via a water meter. The quantity introduced is such that a sufficiently high level at the bottom of the column is obtained.

2. **Testing the line-up for leaks: ½ hour.** Water is circulated to check the pumps and the rest of the line-up for leaks.

3. **Introducing hydrochloric acid: 4 hours.** Acid is delivered to the column from transportable tanks by means of air pressure. The time required for emptying one tank (contents 525 U.S. gallons) is about one hour. On average, four skid tanks of inhibited hydrochloric acid are required per column.

4. **Circulation of 15 percent wt inhibited hydrochloric acid: 8 hours.** After circulation has started, the temperature is raised with live steam to max. 60 C (140 F) and definitely not higher, as otherwise there is the danger that the inhibitor decomposes. At intervals a sample of the circulating liquid is taken; analyses of these samples make it possible to supervise the progress of cleaning.

After the hydrochloric acid concentration of the liquid has fallen to 6 percent wt, concentrated inhibited hydrochloric acid is injected again until the strength of the circulating acid is about 8 percent wt. Then a check is made to see whether acid concentration decreases further or remains constant. In the first case, acid is once again injected, and this process is repeated until the hydrochloric acid and iron contents remain constant. As soon as this point has been reached, circulation of the acid is stopped.

5. **Draining and flushing: 7 to 9 hours.** After the cleaning acid has been run off, the column is flushed with water for 6 to 8 hours. Water must be injected at high pressure, for instance via the fire fighting system of the refinery. Flushing water is drained off and neutralized with caustic soda. After flushing has been completed, steam is led into the column.

6. **Neutralization: 2 to 3 hours.** The required amount of water is introduced into the column after passing through a water meter. Then a 25 percent caustic soda solution is led into the column until the liquid in the column has an alkalinity of 1 to 2 percent wt. The diluted caustic soda solution is circulated for one hour.

7. **Draining and flushing: 3 hours.** The whole system, including the circulation pump, is flushed with water. If the column has to be opened afterwards for inspection, repair, etc., phases 8 and 9 also must be performed.

8. **Steaming out: 4 hours.**

9. **Testing column for gas; opening of column: 3 hours.**

Total time for this column clean-out was 35 hours.

If deposits in the column are predominantly organic a suitable solvent

must be circulated before the work described above can start.

In some refineries, removal of organic deposits from certain columns and heat exchangers is achieved by flushing with gas oil at about 200 C (390 F). The circulating gas oil is led through a furnace in order to keep the temperature at the required level. After the gas oil has circulated for some hours, columns and heat exchangers under consideration are reflushed with hot water.

Flushing with gas oil usually removes organic deposits. If not, the solvent to be used must be determined experimentally.

Sometimes distillation columns are prepared for cleaning as follows: prior to shut-down, feed to the column is decreased for four hours while the column temperatures also are reduced. Consequently, the bottom section of the column is flushed with light products so that the heavier materials present on the column wall and trays are washed down.

Cleaning of Coolers, Condensers and Heat Exchangers

To ensure that the chemical cleaning of tube bundles can be done successfully, care must be taken that these bundles do not become too badly fouled, particularly when cleaning must be done at the tube side.

In those cases where the deposit which has settled in coolers, condensers and heat exchangers proves to be soluble, it can be removed by circulating a cleaning agent. Line-up for such cases is shown in Figure 2. The shell side of coolers, condensers and heat exchangers can be connected to the standard line-up. This must be done in such a way that no air pockets are present in the equipment. The liquid stream should therefore flow upwards.

The cleaning system can be connected to the equipment to be cleaned by removing bends and by incorporating equipment in the line-up by means of reducers. Connections can also be made to nozzles fitted for that purpose on the inlet and outlet of the cooler, condenser or heat exchanger. In the latter case blind flanges should be placed between the nozzles and the inlet and outlet valves. All other connections on the equipment should be blinded.

Both shell side and tube side of coolers, condensers and heat exchangers can be treated with a cleaning agent. A circulation pump is used which pumps the cleaning agent out of a storage tank and via the shell side or the tube side back into this tank.

The cleaning agent is prepared beforehand in the tank, the quantity required being calculated from the dimensions of the equipment to be cleaned. Temperature of the cleaning agent, and also of the flushing water which is used after the acid treatment, can be raised by steam. Once the cleaning solution is ready, circulation can begin, during which—if required—the cleaning agent can be agitated by air or, preferably, an inert gas (see Figure 2).

Coolers, condensers or heat exchangers are flushed with water after the cleaning

agent has circulated for a sufficient time. The fire-fighting line of the refinery again can be used for this purpose with the advantage that the flushing water is injected at high pressure. Flushing water is collected in the circulation tank, where a caustic soda solution is added to neutralize the acid flushing water which is then removed via the drains.

After flushing, a 1 to 2 percent wt caustic soda solution, prepared in the circulation tank, is led through the equipment. Next, the equipment is reflushed with water.

In a special method for cleaning bundles at the shell side, a cleaning agent in the form of a mist is introduced into the equipment. This method has been used successfully on several steam reboilers of alkylation units in which—because of a mishap in operation—fuel was deposited on the tubes at the shell side. A unit shutdown was avoided by injecting a gasoline fraction 100 to 160 C (212 to 320 F) into the steam, running off the condensate via the drains. In this way a thorough clean-out was obtained and the unit did not have to go down, even for a short period. The same method also has been applied to steam condensers with fixed tube sheets and to reboilers in a gas separation unit.

Cleaning of Boilers

Boilers also can be cleaned by means of chemicals; the method to be followed depends on the type of scale present in the boiler. In most cases, boiler scale can be removed with inhibited hydrochloric acid. However, difficulties arise when more than 20 percent silicic acid or more than 60 percent calcium sulfate is present in the scale. In these circumstances a mixed alkaline cleaning solution containing sodium carbonate and sodium hydroxide should be used. It must be kept at 90 C (195 F) for 24 hours at atmospheric pressure in the equipment to be cleaned.[2] If necessary, this operation is followed by cleaning with acid.

For acid treatment, a 10 to 15 percent wt inhibited hydrochloric acid solution can be applied. During cleaning the temperature is gradually raised, the maximum temperature being dependent on the type of inhibitor used. The acid solution is circulated to promote dissolving of the scale. Time required for acid cleaning depends on the thickness of the scale layer; usually it takes some hours. Because hydrogen is produced during this cleaning procedure, an open flame must not be used near the boiler.

After acid cleaning, the boiler is drained, washed three times with a neutralizing-passivating solution and flushed with fresh water. Finally the boiler is washed out with an alkaline solution consisting of condensate or boiler feed water to which 20 to 30 g of sodium carbonate per litre has been added.

If a boiler is also fouled with oil, the heat transfer may be considerably reduced. In such cases, cleaning can be effected by filling the boiler with a highly alkaline soap solution, for instance 30

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(2) In practice, the alkaline solution sometimes is kept boiling. It should be noted that this may lead to stress corrosion.

Figure 2—Standard line-up for cleaning heat exchangers.

percent wt yellow soap, 50 percent wt trisodium phosphate, 10 percent wt borax and 10 percent wt sodium hydroxide as a 10 percent solution in water. This solution is boiled for about 24 hours at atmospheric pressure; then the boiler is drained and flushed with water. This method removes practically all the deposited oil. Afterwards the layer of scale can be removed by chemical cleaning.

Cleaning of Drums

Experience has shown that the following procedure for cleaning drums is most satisfactory.

1. Steaming out: The drum to be cleaned is steamed to remove the last traces of oil and to ensure good results during the next step.

2. Pickling: Pickling is carried out for a few minutes, using 15 percent wt hydrochloric acid to which an inhibitor and a wetting agent have been added. The drum being treated is partly filled with the pickling agent, closed and rotated through its longitudinal axis.

The hydrochloric acid concentration of the pickling solution must be checked periodically. If this concentration falls below 10 percent wt, concentrated inhibited hydrochloric acid should be added until a concentration of 15 percent wt HCl has been reached.

3. Flushing: After pickling, the drum is flushed—again for a few minutes—with either condensate, drinking water or brackish harbor or estuary water. The drum must be carefully drained after flushing. Instead of water, a spent neutralizing solution may be used for flushing.

4. Neutralization: Water remaining in the drum after flushing is neutralized for three minutes with a 5 percent wt solution of a 1:1 mixture of trisodium phosphate and caustic soda. For making this solution, soft water (for instance condensate) has to be used; the sodium chloride content of the neutralizing solution must be regularly checked during use.

5. Drying: After the neutralization step, the drum is dried with hot air for a few minutes. The outsides of the drums are cleaned by blasting with steel grit.

Potential Corrosion Difficulties

In many cases chemical cleaning of equipment has given good results, but occasionally the effect of this cleaning method has been disappointing. An example of a case which offered some corrosion difficulties because of inadequate precautions was the chemical cleaning of some columns containing trays which are susceptible to plugging unless all lines in the stripper system are thoroughly clean. In order to achieve this, a chemical cleaning operation was carried out by a contractor.

The procedure adopted was as follows: (1) degreasing at 70 C (160 F) by means of a 3.5 percent wt sodium carbonate solution containing sodium metasilicate as a wetting agent (48 hours); (2) flushing with cold water (10 hours); (3) acid cleaning at 70 C with 6 percent wt hydrochloric acid, containing 0.05 percent wt of mono-orthotolyl thiourea as a corrosion inhibitor and a wetting agent of the alkyl phenol polyglycol ether type (filling 15 hours, circulation 20 hours, draining 5 hours); (4) flushing with cold water (10 hours); and (5) neutralizing with a 2 percent wt sodium carbonate solution at 40 to 50 C (104 to 122 F) (10 hours).

Additional acid had to be added to the system to maintain the required acid concentration; the actual HCl concentration never exceeded 6 percent wt. Control of the acid cleaning step was secured by measuring the iron content of the acid and by estimating the concentration of the ferrous and ferric ions present.

After the cleaning operation had been finished, the columns were found to have suffered some damage owing to corrosion. The attack occurred principally on parts made from 12 to 14 percent chrome steel, especially at places where this steel was in contact with large areas of mild steel, and only to a small extent on parts made from mild steel.

In order to trace the cause of the damage, corrosion tests were conducted in the laboratory using, in addition to

mono-orthotolyl thiourea, four commercial corrosion inhibitors and varying the temperature and contact time.

From the results of this laboratory check-up, it could be concluded that the inhibiting effect of mono-orthotolyl thiourea had been insufficient. Furthermore, at the inhibitor concentration and temperature applied during the acid cleaning step, none of the compounds tested would have given adequate protection to the construction materials. Finally, results indicated that 12 to 14 percent chrome steel is more liable to attack than mild steel, especially if the chrome steel surface is relatively small compared with the mild steel surface.

Even the results of this limited investigation point to the importance of carefully checking the properties and activities of unknown inhibitors before they are applied in chemical cleaning operations.

This case is not representative of chemical cleaning in general, and was chosen to stress the necessity of taking adequate precautions.

Auxiliary Equipment

Line Blinds

It is important that the blinds (spectacle or spade type) be stored in a convenient manner and be well maintained. For each plant a list of blinds is available. If inspection and/or overhaul of a plant is to take place, all necessary blinds are sorted in storage and made ready for use. The clean-out personnel then lays, alongside each part of the equipment, the required blinds with the corresponding gaskets. Clean-out personnel also install the blinds.

After the inspection and/or overhaul have been completed, blinds are removed by the clean-out personnel. The blinds are taken to storage, inspected and returned to their places.

Supervision of the installation and removal of the blinds is exercised by plant personnel who are responsible for industrial safety.

Tanks

For the transport of hydrochloric acid, rubber-lined tanks must be available. Experience has shown that for the cleaning of columns four tanks, each with a capacity of about 525 U.S. gallons, normally are required. Figure 3 is a diagram of such a tank. In addition to the manhole, a 6-inch nozzle is fitted on the tank; the 2-inch dip pipe is made of plastic. A 4-inch nozzle at the bottom of the tank is connected to an acid resistant valve.

For ease of transportation, tanks can be placed on trailers (see Figure 4).

In addition to the acid storage tank and tanks for transportation, a circulation tank with a capacity of about 1050 U.S. gallons must be available; this tank is not rubber-lined. Furthermore, it is often worthwhile making a smaller vessel, with a capacity of about 300 litres, for use in cleaning small parts of plant equipment such as cooling water jackets.

When cleaning agents are used which
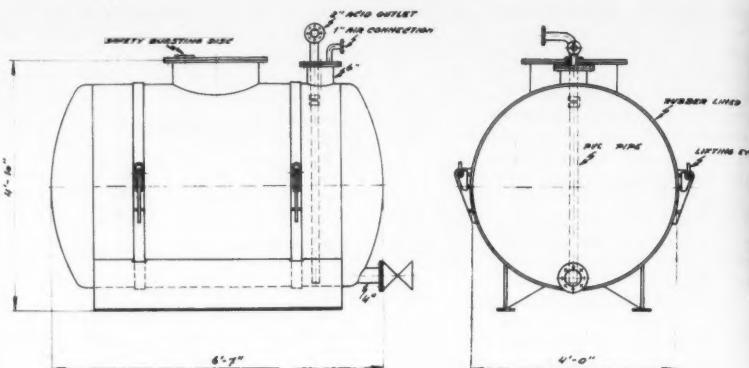
Figure 3—Tank for transport of hydrochloric acid (500 gallons).
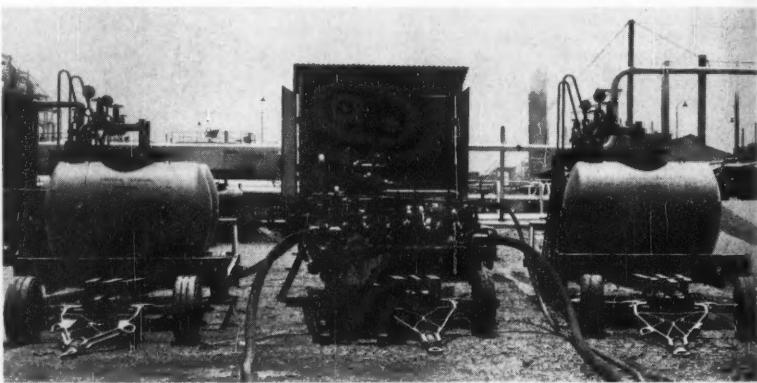
Figure 4—Tanks for chemical cleaning mounted on trailers for ease of transporting cleaning agents at a refinery.
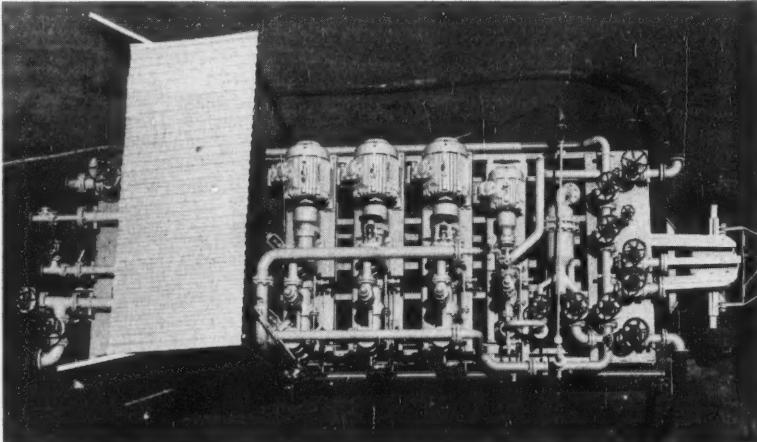
Figure 5—Pumps for chemical cleaning are mounted on trailer for mobility at a refinery.

attack the rubber lining of tanks, for example organic solvents, a special tank must be available for these products. The circulation tank also can be used for this purpose.

Pumps

Because experience has shown that reciprocating pumps are unsuitable for

circulating hydrochloric acid, the use of centrifugal pumps is advised. For example: a turbine-driven centrifugal pump without a stuffing box, suitable for air or steam at 6 kg/cm2 (85 psia) and 8 to 10 kg/cm2 (113 to 142 psia) respectively. The pump should have sufficient delivery head; its capacity should be at least 40 m3/hour. The pump must

TABLE 4—Hoses Used in Chemical Cleaning Work

TYPE	NUM-BER	Length, Meter	Ins. Diam. Inch	REMARKS
Suction hose.........	12	7–8	4	Acid, alkali and solvent-proof. Max. temp. 70-100 C (158-212 F). Resistant to wear caused by bumping
Delivery hose........	6	7–8	4	Ditto
Delivery hose........	12	7–8	3	Ditto. Max. pressure 10 atm (150 psi)
Water hose..........	8	20	2	Max. pressure 6 atm (90 psi)
Hose for concentrated caustic............	8	20	2	Resistant to caustic of 60° Bé. Max. pressure 6 atm (90 psi)
Hose for concentrated acid (HCl).........	8	20	1½	Resistant to 30-35% wt HCl
Flushing hose........	8	20	2½	Max. pressure 3 atm (45 psi). Fitted with a bayonet coupling for connection to fire-fighting line
Steam hose..........	16	10	2	Max. pressure 10 atm (150 psi)
Venting hose........	10	20	1	

Figure 6—Tool truck used by clean-out personnel in chemical cleaning operations at a refinery.

be suitable for working at temperatures up to 100 C (212 F).

Pumps used in cleaning operations can be made from high silicon iron alloy, a completely acid-resistant brittle material. Because of this brittleness, pumps of this type are armored and must be handled with great care. A supporting frame should be used to install the pump, and all connections to the pump manifold should be made by rubber hoses. The pump is mounted on a trailer as shown in Figure 5.

To be certain that one pump will be ready for use in a cleaning operation, spare pumps should be kept in stock.

Hoses

Table 4 gives a list of hoses which are used for chemical cleaning work at a large refinery.

For each refinery, the number of hoses required for chemical cleaning must be determined separately. It has been found that once the hoses are available, great use is made of them. A sufficient number must be ordered because these hoses are subject to considerable deterioration and must be replaced often for safety reasons.

Valves, T-pieces, Bends, etc.

For chemical cleaning work, valves, bends, etc., made according to ASA 150 lbs are satisfactory.

Trucks

Practice has shown that a tool truck at the disposal of the refinery's clean-out service is of great value (see Figure 6). This truck may be regarded as a branch of the central tool stores, from which the truck is stocked and replenished. During the time the truck is in operation, an administrative employee from the central tool stores is present in the truck and is in charge of its contents.

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(b) C. E. Imhoff and L. A. Burkardt. X-ray Diffraction Methods in the Study of Power Plant Deposits, 1276-1288;
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L. S. Van Delinder. Modern Cleaning Methods for Tankage Equipment. *Corrosion*, 13, No. 6, 359t-360t (1957) June.

DISCUSSION

Question by Douglas Webster Speed, Esso Standard Oil Co., Baton Rouge, Louisiana:

Do you place a limitation on the use of inhibited HCl in cleaning austenitic stainless steels 18-8 Cr Ni, 25-20 Cr Ni?

Reply by Lambert N. Klinge and Johan Selman:

A case is quoted in the article in which attack occurred during cleaning with inhibited hydrochloric acid on parts made of 12 to 14 percent chromium steel. We can add that 18 Cr 8 Ni steel nuts and bolts which were also in the equipment being cleaned, were left completely unattacked under the prevailing conditions. Thus it appears that 18 Cr 8 Ni steel requires no limitation in the use of inhibited hydrochloric acid during chemical cleaning. We feel the same applies to 25 Cr 20 Ni steel.

However, as yet we have insufficient experience in this field to make this statement without any restrictions. If we had to carry out chemical cleaning with inhibited hydrochloric acid of equipment made of these steels, we certainly would take no risks and would conduct extensive tests in the laboratory before beginning the cleaning operation.

Reference is made to the article by Uhlig.*

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* H. H. Uhlig and E. M. Wallace. Effect of Hydrochloric Acid plus Inhibitor on the Corrosion Resistance of 18/8 Stainless Steel. *Trans. Electrochem. Soc.*, 81, 511-520 (1942).

Any discussion of this article not published above will appear in the June, 1960 issue.

10-Year Index to Corrosion Magazine

An alphabetical subject and author index of the first 10 years (1945-1954) of CORROSION is available. A chronological table of contents of each issue is included. Write to CORROSION, National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Texas.

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Selection of Alloys
For Refinery Processing Equipment*

By A. J. FREEDMAN, G. F. TISINAI and E. S. TROSCINSKI
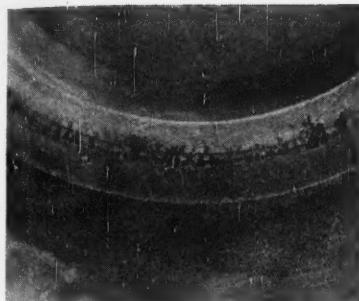
Figure 1—Corroded face of Type 316 stainless steel relief valve seat on a modern pipe still fractionation tower.
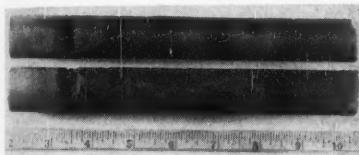
Figure 2—Characteristic impingement attack on reboiler tubes from a petrochemical unit.
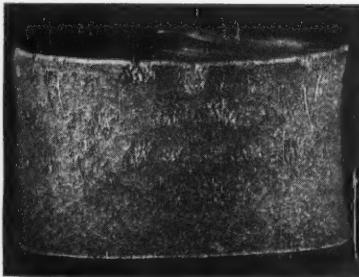
Figure 3—Section of a tube from a fluid hydroformer re-cycle gas furnace. Cracks opened upon bending in laboratory.
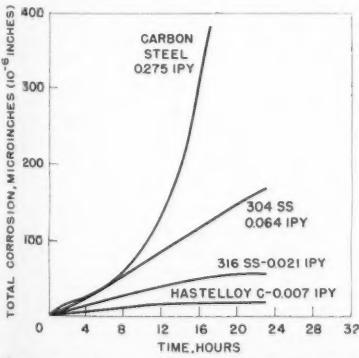
Figure 4—Typical corrosion information gathered from a laboratory screening test. Corrosion rates are shown in an organic acid solution containing process impurities at 104 F.

Introduction

REFINING CONDITIONS in the present push for higher octane gasoline are becoming more and more severe. New and valuable petrochemical processes will demand process conditions differing considerably from those in the refining industry today. For these reasons, plus the ever-present need to select the most economical materials of construction, careful selection of alloys is becoming increasingly important. Preconceived ideas concerning use of particular alloys under certain conditions and treatment of these alloys during construction should be discarded in favor of a carefully planned and executed evaluation program. This program should consider all possible variables which might influence alloy performance during construction and normal operating cycles, including both on-stream and shutdown periods.

Effects of Process Variables

A dramatic example of the effect of process variables upon corrosion rates of common alloys is the problem of high temperature sulfidic corrosion in reformers. Low chromium-molybdenum steels have been used for many years in furnace tubes on crude units, thermal cracking units and hydroforming units processing sour stocks. When the newer catalytic reforming units were first designed, it appeared so logical to specify these same alloys for high temperature furnace tubes that little attention was paid to possible new corrosion problems.

Problems arising from use of alternating process and regeneration conditions, on the other hand, were anticipated and studied thoroughly with the result that problems have been practically non-existent in operating units. But these early units were plagued by plugged catalyst beds, poor conversion and other troubles resulting from the accumulation of large quantities of loose, brittle scale. Only when the magnitude and importance of this problem became clear were studies made to understand the corrosion problems of these reforming processes. Careful control of H_2S/H_2 ratios and use of properly heat-treated 18-8 stainless steel or properly aluminized low alloy steel furnace tubes have almost eliminated corrosion and scaling problems in catalytic reformers. This experience, throughout the industry, has awakened most refiners to the dangers of basing alloy selections only on past experience when new and untried processes are developed.

When alloys are selected for a new unit or process, all conditions to be expected during normal operating cycles must be considered. For example, a modern pipe still had several forced shutdowns in quick succession when the unit

Abstract

Discusses variables in a refinery which affect selection of alloy materials to be used in construction of units. Gives examples of failures caused by lack of evaluation of alloys in new processes before fabrication of units. Presents reasons a laboratory and pilot plant corrosion testing program should be established and information on effects of temperature, concentration and time that should be obtained from this program. Also discusses metallurgical considerations which should be made in selection of alloys: weld metal structure, grain boundary precipitation effects in stainless steels and in other alloys, problems in clad vessels, stress corrosion cracking in alloys and effects of hydrogen on alloys. Emphasizes the need to maintain effective records of tests, chemical composition and heat treatment history of each specimen. Briefly discusses need to continue alloy evaluation by corrosion monitoring in process equipment.   6.5

was new. These shutdowns were caused by leaky relief valves on the primary tower. Type 316 stainless steel valves were installed during initial construction of this unit. Normally, this alloy would be entirely satisfactory in the process fluids found in this unit. However, small amounts of sour naphtha and hydrochloric acid collected in narrow crevices around the valve seats and rapidly increased in corrosivity.

This phenomenon, known as crevice corrosion, occurs when circulation or diffusion in narrow spaces is not sufficient to maintain the normal stream composition at these points. Valve seats on the relief valves corroded rapidly, and the valves could not be closed properly. Figure 1 shows the corroded face of one of these valve seats. Solving this problem, once it was discovered and understood, was not too difficult. Hastelloy B alloy facings, resistant to acid attacks, were substituted for the Type 316 steel on valve seats and discs, and the problem disappeared.

Another specific operating variable which has caused considerable difficulty in refinery units is impingement attack. On a petrochemical unit, for instance, reboiler tubes which were struck by a high velocity, high temperature stream of corrosive fluids corroded severely. Figure 2 shows the characteristic grooved appearance of tubes removed from this unit. In this case, laboratory tests indicated that, rather than substitute more expensive alloy tubes, the problem could be solved more economically by modifying the process stream. Addition of oxidation inhibitors to prevent formation of corrosive components effectively eliminated impingement attack.

In addition to conditions during normal on-stream operations, corrosive environments existing during shutdowns also must be considered when selecting alloys. Re-cycle gas furnace tubes on a fluid hydroformer were constructed from

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Type 304 stainless steel. This is a standard material for this application, and no corrosion was expected. However, leaks occurred in these furnace tubes after only a few months' operation. These leaks were found only near butt-welded joints. Sections of the tubes, with cracks which appeared upon bending in the laboratory, are shown in Figure 3.

New welded tubes were found to be metallographically sound although some circumferential shrinkage of the tubes had occurred near welded joints. This shrinkage was noted during construction of the unit but was not considered serious.

No ready explanation could be found for the failure of these tubes. However, laboratory corrosion tests using solutions similar to those in the tubes during shutdowns indicated the answer: intergranular stress corrosion cracking caused by aqueous condensates containing H_2S and SO_2. These gases react in the presence of water to form polythionic acids. These acids are known to stress crack 18-8 stainless steels intergranularly, once the steels have become sensitized by heating in the proper range of temperature.[1] Normal fabrication procedures provided the stress, normal operating temperatures provided the sensitization, and normal shutdown procedures provided the cor-

rodant. The result was a troublesome failure which was not detected until the unit was back on stream.

In any case of corrosion failure, resistant alloys can be selected to fit the process, or the process can be modified to accommodate available materials. In the case of the fluid hydroformer, the economical solution was to change the shutdown procedure to keep the furnace tubes free of condensate. Many other instances of corrosion during downtime have been recognized in recent years. The importance of controlling corrosive environments during shutdowns cannot be overemphasized, especially when expensive alloys and critical heat treatments were used during initial construction of a unit.

External and internal operating conditions must be considered in selecting alloys. For example, in plants near salt water, normal condensation occurring in the evening after a warm day may contain appreciable amounts of salt, even salty to the taste. During warm days, this condensate tends to dry up, leaving salt behind. During the evaporation process, conditions are ideal for transgranular stress corrosion cracking of austenitic stainless steels. The danger of stress corrosion cracking can be minimized only by such means as proper heat treatment after cold forming operations or possibly by use of protective coatings or cathodic protection.

Similar favorable conditions for stress corrosion cracking may arise from use of salt or brackish water in exchangers containing stainless steel or from having any of several different types of insulation in contact with stainless steel. There seems to be enough residual chlorides in many insulations to cause stainless steel to stress corrosion crack from moisture picked up during normal condensation. It is extremely difficult to seal such insulation completely against the entrance of water vapor, if not liquid water. The mere fact that stress corrosion has not appeared in older units is not a positive guarantee that it will not appear in new units if conditions otherwise seem to be favorable. Not enough is known about this type failure to make assurances of its occurrence or non-occurrence under any circumstances.

Laboratory and Pilot Plant Corrosion Testing

A poor choice of metals for new unit construction can lead to costly and sometimes hazardous failures in critical parts. Also, preliminary corrosion experience may have a vital influence on the economic decision to construct a commercial process. That is, a new unit which is technically attractive may be economically unsound because of high material cost needed to contain the process corrosion-wise.

Because of its importance, a corrosion-testing program for a new process or unit should begin as soon as feasibility of the process has been established. This program in general should consist of two parts. First, a preliminary laboratory study should be made to screen possible materials for construction of a pilot

plant. Second, a combined laboratory and pilot plant program should be planned to study, from the chemical, process and metallurgical viewpoints, all corrosion problems expected in the commercial unit.

Preliminary Work

Because it is impossible to duplicate an entire refinery or chemical process unit in the laboratory or even in a pilot plant, any corrosion testing program should begin with a careful study of the process. Flow sheets should be examined for critical locations from a corrosion viewpoint. Laboratory tests then can be devised to reproduce, as closely as practicable, all operating conditions at these locations. This is essential. Omission of one variable such as impingement or presence of crevices, for example, can lead to a false estimate of alloy behavior at the location.

Once laboratory equipment is available, materials to be tested are selected. If corrosive components in the process stream are known, the corrosion literature may provide valuable clues. Published information cannot always be used as a final authority; small changes in operating variables such as stream concentration or temperature can affect profoundly the corrosivity of the fluids. If no past experience is available, metals ranging from carbon steel to the so-called superalloys must be considered.

Judicious metal selection for initial testing can save time in later evaluations. Any metals examined must be capable of withstanding the physical stresses of normal service, must be readily available at a reasonable cost and must be amenable to fabrication by standard methods. It would be foolish, for example, to evaluate an alloy available only in cast form as a possible material for tubing or pipe.

From a relatively few laboratory tests, much information can be obtained. Types of alloys required in the construction of the pilot plant equipment can be determined readily. Figure 4 shows typical corrosion information which can be gathered in laboratory screening tests. These data were obtained from a single corrosion test in an organic acid solution containing process impurities at 104 F by means of laboratory corrosion probes. Corrosion probes have been described in earlier publications.[2-5]

From the graph, it can be seen that carbon steel, corroding at 0.275 inches per year, would be totally unsuitable for use in this service. Even Type 304 stainless steel, with a corrosion rate of 0.064 inches per year, does not appear to have any merit. Type 316 stainless steel, with a corrosion rate of 0.021 inches per year, looks promising and probably is a good construction material for the pilot plant equipment. This alloy seems especially encouraging; the corrosion appears to be decreasing to a negligible value after approximately 20 hours. This effect can be caused by protective film formation or possibly by depletion of the corrosive agent in the solution. Such beneficial effects may not always be realized in an actual process, especially under high velocity conditions or in a continuous proc-

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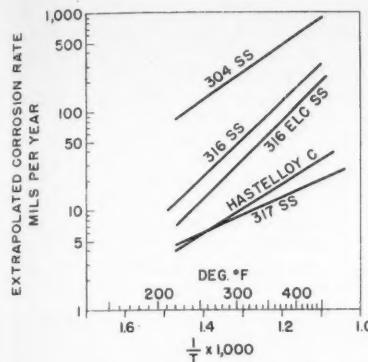
[Figure 5—...]

Figure 5—Effect of temperature on corrosion rates predicted from Arrhenius equation.

Figure 6—Effect of distillation residue temperature on corrosion rate of Type 316 stainless steel.

Figure 7—Effect of organic acid concentration on corrosion rates at boiling temperature.

ess in which the depletion effects are negligible. The last alloy shown, Hastelloy C, corroding at 0.007 inches per year, should be relied on for excellent corrosion protection if subsequent work proved Type 316 stainless steel to be unsuitable.

When alloys are chosen for a pilot plant, it is important to remember that the plant probably will provide product samples having high purity for consumer evaluations. A considerable amount of time and money may be required to purify products if the materials used for pilot plant equipment are not selected carefully to prevent contamination by corrosion products.

Corrosion Testing During Process Development

In the combined laboratory and pilot plant work following the initial laboratory tests, a judicious corrosion evaluation program is required. Here, all possible variables such as temperature, stream composition, alloy microstructure, fabrication procedures and possible occurrence of various types of corrosion should be evaluated thoroughly, both in the pilot plant equipment and also under simulated process conditions in the laboratory. Similarly, external conditions at the proposed plant location should be considered. For example, atmospheric pollutants and the type cooling water available can be limiting factors in the choice of certain construction materials.

Temperature Effects. In many cases, final operating temperatures of a commercial process are not determined until near the end of the pilot plant study. Hence, it is important that construction alloy corrosion rates be determined over the entire range of possible temperatures. In many cases, temperature effects on corrosion rates can be predicted from the Arrhenius equation.* If the Arrhenius Equation is valid, a plot of the corrosion rate logarithm against the absolute temperature reciprocal should result in a straight line, as shown in Figure 5. This type information is useful in predicting corrosion rates. Knowing that a particu-
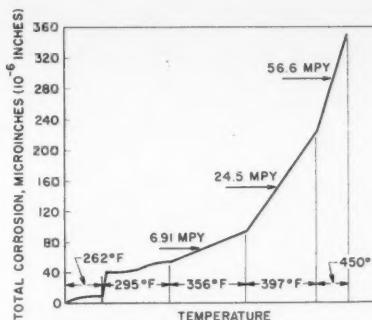
* Arrhenius Equation: Corrosion Rate $= Ke^{\frac{-Q}{RT}}$

where $\text{Ln Corrosion Rate} = -\frac{\text{Constant}}{\text{Temperature}} + \text{Constant}$.
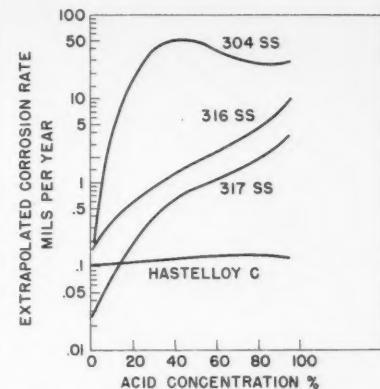
lar type of corrosive environment behaves in this manner enables one to interpolate or extrapolate corrosion rates over a wide temperature range.

Temperature has another important effect on corrosion rates. Metals or alloys can corrode by one or more mechanisms, depending upon temperature of the corrosive medium. Corrosion rates can decrease with exposure time, remain constant with time, increase with time or combine all three effects. The corrosion mechanism is important when the results of short term corrosion tests are extrapolated to a yearly basis. As an example, the effect of distillation residue temperature on the corrosion rate of Type 316 stainless steel is shown in Figure 6. The conditions shown in this graph are typical of those found in a distillation column where a wide range of temperature is normal. In this application, Type 316 stainless probably would be a suitable construction material at temperatures to about 350 F. In this temperature range, the protective oxide films on the surface of the stainless steel appear to be maintained; at higher temperatures, the films break down and accelerated corrosion occurs.

Concentration Effects. Stream concentrations can have important effects on corrosion rates. Unfortunately, corrosion rates seldom are linear with concentration over wide ranges. In equipment such as concentrators, reactors and distillation columns, concentration changes occur continuously, making prediction of corrosion rates difficult. The effects of boiling acid at different concentrations on the corrosion rates of several alloys are shown in Figure 7. In this application, the concentration of acid did not appear to influence the corrosion rate of Hastelloy C. Corrosion rates of Types 316 and 317 stainless steels increased continuously with increasing acid concentration. Type 304 stainless showed an apparent maximum at about 40 percent acid. At higher concentrations, the corrosion rate decreased to a substantially constant value.

Time Effects. Metals or alloys can corrode by one or more mechanisms. In this situation, corrosion rates often are expected to change with time. Figure 8 illustrates typical corrosion-time curves. The rate of attack may (1) remain constant with time as shown in Figure 8A, (2) slow down at a rate inversely propor-

tional to the thickness of the scale as shown in Figure 8B or (3) virtually stop after a rapid initial attack of limited magnitude as shown in Figure 8C.

The attack rate also may be more complex. For instance, the curve in Figure 8D has a range in which the corrosion accelerates with time, and the curve in Figure 8E consists of small parabolas, each parabola corresponding to scale growth, and each break in the curve to a fracture of the scale, followed by a healing of the breaks. Once the characteristic rate type is established, reasonable extrapolations can be made from short tests to long time exposures. Also, possible ways of controlling corrosion may be suggested by these data.

If intergranular corrosion, stress corrosion cracking, hydrogen embrittlement or hydrogen blistering should occur, the time factor may be of little importance. If these types of corrosion are observed in any application, the material generally is considered to be unsuitable, and other materials are selected or some other equally safe and positive corrective measure is taken. The risk of a sudden, unpredictable and uncontrollable failure caused by one of these mechanisms cannot be taken in any commercial unit or pilot plant. Only in cases of uniform attack and pitting are rates of propagation considered and corrosion allowances established.

Velocity and Impingement Effects. Many laboratory tests and pilot plant operations may be conducted under conditions somewhat less severe than those which will occur in the actual operating unit. Stream velocities in particular may be lower. This can be extremely important so far as corrosion resistance is concerned because many materials depend upon formation of a protective surface film to provide corrosion resistance. If this film is removed by exposure to a high velocity medium or by impingement of dispersed gases or similar disturbing elements upon the metal surface, the corrosion rate can be much higher than it would be if the film were permitted to form in its normal fashion.

Depending largely upon chemical composition, some alloys are susceptible to this type of film formation and others
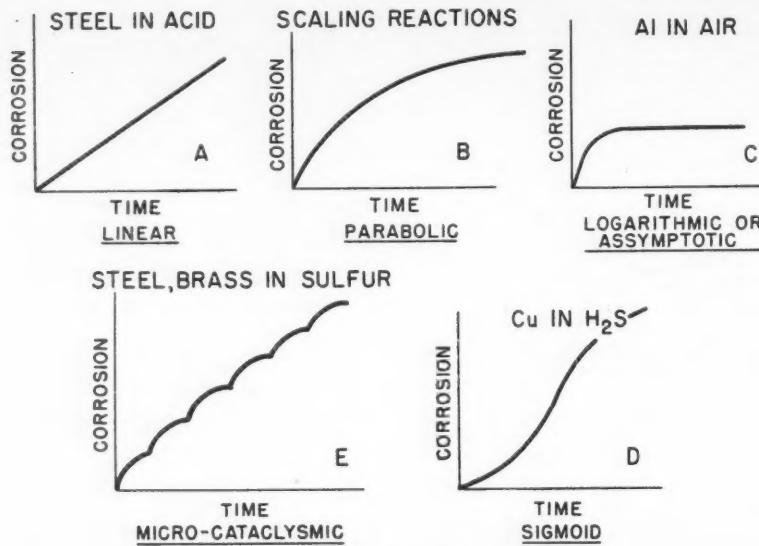
Figure 8—Schematic corrosion-time curves.
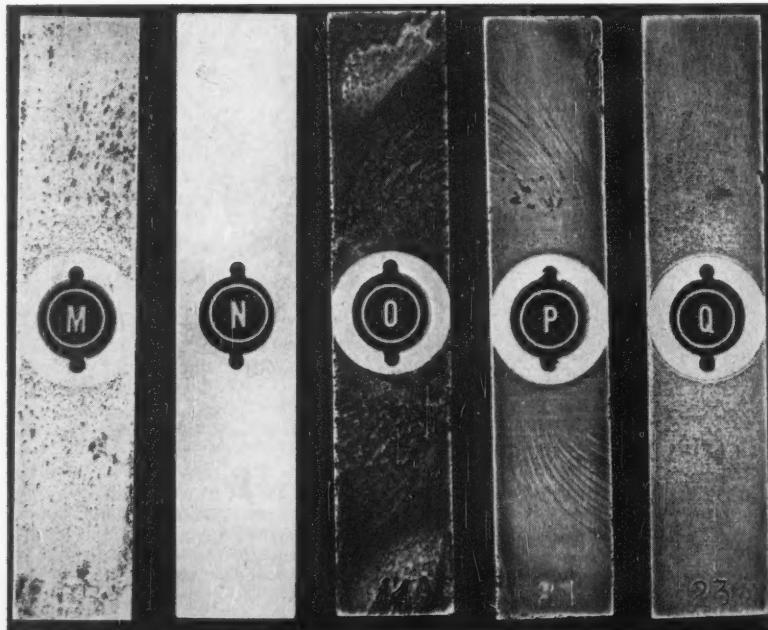
Figure 9—Velocity effects in a corrosive stream from a petrochemical process. Specimen M: Type 304 stainless steel. Specimen N: Type 316 stainless steel. Specimen O: carbon steel. Specimen P: Type 410 stainless steel. Specimen Q: Hastelloy B.

are not. For example, the corrosion resistance of Hastelloy C does not seem to depend at all upon film formation, whereas that of Hastelloy B seems quite dependent upon this effect. Sensitivity to velocity or impingement effects can be studied adequately in the laboratory if the pilot plant does not provide suitable conditions, but information must be available to cover the range of stream velocities expected in the final operating units.[6] Also, if a realistic evaluation is to be made, such tests must be conducted under actual operating conditions of temperature and pressure and with actual process streams. This is essential because minor components in plant streams, which can-

not be introduced readily in synthetic laboratory solutions, may be the main culprits in causing severe velocity corrosion.

An example of the effect of velocity or impingement on corrosion rates is shown in Figure 9. Samples shown were exposed in a corrosive stream from a petrochemical plant. They were rotated at a peripheral speed of 1130 fpm. Typical velocity effects can be seen on the Types 304 and 410 stainless steels, carbon steel and Hastelloy B. Type 316 stainless steel was not affected.

Galvanic Effects. When dissimilar metals are used in contact with each

other and are exposed to an electrically conducting solution, combinations of metals should be chosen that are as close together as possible in the galvanic series. Coupling two metals widely separated in this series generally will produce accelerated attack on the more active metal. Often, however, protective oxide films and other effects may reduce or eliminate galvanic corrosion. Final decision in each application should be made on the basis of thorough laboratory and pilot plant study of galvanic tendencies on the metals involved.

Effects of Additives and Process Changes. Corrosion rates often can be affected greatly by minor amounts of special compounds added to process streams. Corrosion inhibitors, for example, have saved millions of dollars in the petroleum industry by eliminating the need for expensive alloy construction. Anti-oxidants added in small amounts to certain streams can prevent formation of corrosive organic peroxides and acids. Nitrogen blanketing of storage tanks accomplishes a similar purpose. In some cases, addition of a drying tower may eliminate small amounts of corrosion producing moisture from an otherwise innocuous stream. Alternatively, in other cases dilution of this corrosive moisture with relatively large amounts of water may render it less dangerous.

These possibilities may produce large savings in capital investment costs by permitting use of carbon steel, for example, instead of expensive alloys. Careful laboratory and pilot plant testing usually will indicate the value of these methods in a particular case. Of course, the required purity of the final products from a chemical plant may prevent use of additives for corrosion-control.

Metallurgical Considerations

General Selection

Although a metal of a given type may be necessary to provide resistance to a corroding medium, the metal's corrosion resistance may vary over a relatively wide range, depending upon its metallurgical structure. Properties of a metal or alloy may be either structure-sensitive or structure-insensitive. In general, corrosion resistant metals are sold commercially in the condition in which they have optimum corrosion resistance. Hence, the preliminary weeding-out tests, conducted at the bench scale stage, should be made using commercially as-received materials. These tests will establish which basic type alloys (for example, nickel-rich, copper-rich, aluminum-rich, stainless steels, etc.) should be considered for further study. Often this general information is known from data in the literature.

Microstructural Effects

Weld Metal Structure. Plant equipment is built mainly from wrought material, fabricated largely by welding. The welding operation can introduce objectionable features which should be evaluated. Deposited weld metal has a structure similar to that of a casting although possibly not quite as coarse grained. Figure 10 shows normal metallurgical struc-

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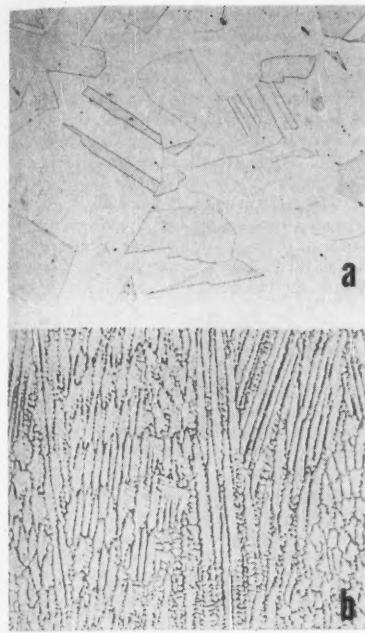
Figure 10—Section A: Austenitic grain structure of a wrought AISI Type 304 stainless steel in the solution-treated condition. 125X, electrolytic oxalic acid etch. Section B: Structure of an AISI Type 317 stainless steel weld deposit. Cored structure is shown by delicate differences in shading of the austenite matrix. 125X, Glyceregia etch.
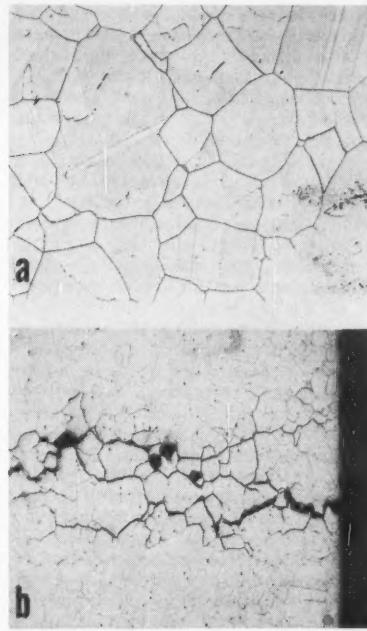
Figure 11—Section A: Type 304 stainless steel has become sensitized, that is, has formed a continuous grain boundary carbide network. 125X, electrolytic oxalic acid etch. Section B: Intergranular attack of a sensitized austenitic stainless steel shown at low magnification. 25X, Glyceregia etch.
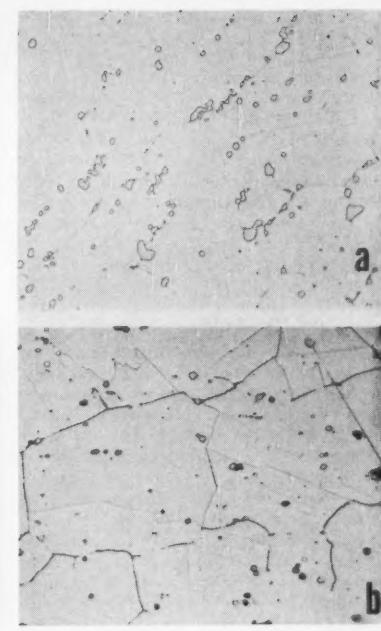
Figure 12—Section A: Structure of a properly solution-annealed Hastelloy C alloy. Small discrete particles are carbides but are not of a harmful type. 250X, alcohol-bromide etch. Section B: Structure of an improperly solution-annealed Hastelloy C alloy. Precipitate shown in grain boundaries makes this structure susceptible to intergranular attack. 250X, Aqua regia etch.

tures for typical stainless steels in the as received (wrought and solution treated) and the weld deposited (cast) conditions. The weld metal has a cored structure, consisting of micro-regions of varying chemical compositions, a result of solidification directly from the molten state. The cored structure may be undesirable in severe corrosive media because an interdendritic corrosion may worm into the metal. However, this effect is not normally met in most processing media. Satisfactory homogenization of the cored weld structure may require heat treatments from four to eight hours or sometimes even longer at rather high temperatures. Such heat treatments may or may not be practical.

Grain Boundary Precipitation Effects in Stainless Steels. Welding also produces a heat affected zone in the base metal on each side of the weld metal. This zone is that region in which temperature has risen enough to permit metallurgical reactions to take place during welding. In some metals such as stainless steels and high nickel base alloys, this can lead to a condition known as sensitization.

Sensitization also can occur in a solution-annealed structure if the metal is held for a sufficient time at temperatures between 800 and 1500 F. A typical sensitized structure in stainless steel is shown in Figure 11A. A continuous precipitate, actually a chromium carbide in stainless steels, occurs in the grain boundaries. In weldments, this precipitation is localized near the base metal which is adjacent to the weld. Accelerated attack can occur in these sensitized zones because of chromium depletion in the metal adjacent to the grain boundaries resulting from this

precipitation or because of galvanic effects induced by it in conjunction with the matrix. This may lead to a knife-edge attack in weldments in the heat affected region. Where the entire base metal has been sensitized by an appropriate heat treatment, there may be a general loss in adherence between the metal's grains. This destroys the material's physical properties. Figure 11B illustrates the nature of the corrosive attack in a sensitized region of a stainless steel.

Various ways have been found to eliminate sensitization in stainless steels. Because the principal rapid precipitant in stainless steels is known to be a chromium carbide, precipitation should not occur if the carbon content of the material is decreased to a low enough value. The present specification limit for so-called extra low carbon (L or ELC) materials is 0.03 percent carbon. This, unfortunately, often is interpreted by the mills to mean 0.035 percent carbon. Accurate analyses are difficult to make for carbon in stainless steels. Also, there may be some question as to carbon content uniformity throughout a large heat of material. Consequently, carbon contents may vary widely from the specified limit, and the actual advantage of the ELC grades for high corrosion resistance may not always be obtained.

Another method to avoid sensitization in stainless steels is through chemical stabilization. Addition of proper amounts of niobium (still called columbium by most American metallurgical companies) or titanium to the stainless steels, followed by appropriate heat treatment—preferably about 1600 F, will cause the carbides to precipitate throughout the metal structure as discrete niobium or ti-

tanium carbides, rather than preferentially at grain boundaries as continuous chromium carbides. Consequently, the corrosion resistance is not affected adversely so far as sensitization during welding is concerned. If weldments are held for short periods at temperatures near 1200 F without prior 1600 F treatment to precipitate the carbides, the heat affected zones may become sensitized even in the presence of niobium or titanium.

Another method of avoiding sensitization in stainless steels is called thermal stabilization. This method is based upon the principle that the grain boundary precipitate of chromium carbides is least harmful in the form of discrete particles which do not have much particle-to-particle contact. The precipitate can be separated in this way by use of special heat treatments before the metal is put into service. For stainless steel, a minimum of four hours at 1600 ± 25 F is required. However, as in the chemically stabilized steels, it is not wise to hold weldments of such a heat treated steel at temperatures near 1200 F unless the steel is again heat treated at 1600 F after welding.

If service temperatures fall between 800 and 1500 F, an intermetallic phase called the sigma phase may form slowly in most stainless steels. Formation of sigma phase drastically reduces the impact ductility and in some cases the corrosion resistance of stainless steels. Sigma phase formation may destroy the beneficial effects of chemical and thermal stabilization in these alloys.

Grain Boundary Precipitation Effects in Other Alloys. Other alloys also de-

velop sensitized microstructures which make them susceptible to intergranular desired medium before being applied attack in appropriate media. For example, copper base alloys tend to be susceptible even though no obvious sensitization effects can be noted in their microstructures. This is especially true in ammonia containing media. Recently, there have been some reports that a modified type of aluminum bronze may be immune to many of the media that normally attack copper base alloys intergranularly. Although the reports seem promising, any such alloy should be tested in the desired medium before being applied extensively.

Effects of microstructure upon corrosion rate may be important even with the most highly corrosion resistant super alloys. For example, Hastelloys B and C have alloy contents so high that, for most applications, chemical composition alone provides adequate corrosion resistance. Metallurgical structure in such cases is of little importance. However in some respects, the Hastelloys are similar to the stainless steels. The alloys' optimum corrosion resistance is produced by a solution annealing heat treatment which requires a rapid cool from the annealing temperature. Figure 12A shows a good solution annealed structure in Hastelloy-C. However, if this annealing treatment is not carried out properly, the sensitized structure shown in Figure 12B may result with a continuous grain boundary precipitate.

In severely corrosive media, sensitized Hastelloys B and C may corrode intergranularly. Heat affected zones adjacent to welds on these alloys are subject to this attack even though the base metal is solution-annealed. Also, as-cast weld metal may corrode faster than solution-annealed base alloy.

Problems in Clad Vessels

The effect of heat treatment upon corrosion resistance of metals becomes increasingly important when other possible fabrication variables are introduced. For example, corrosion resistant metals frequently are used in a clad form rather than in a solid form to reduce capital investment.

There are four cladding methods in general use today. In one, a sandwich is made of the corrosion resistant metal and carbon steel, sealed around the edges by welding and hot rolled to effect a pressure weld between the plates. The bonding is almost 100 percent.

In another method, the metal is brazed to a steel backing plate. The sheets frequently are available only in relatively small sizes and must be welded to produce the larger plates needed. The nature of these welds must be considered because they can be possible points where corrosion might occur.

In a third process, a loose liner is fastened to a carbon steel shell by electrical resistance welds spaced on appropriate centers, usually 1½ to 2 inches apart. The fourth process is the so-called strip liner process in which a loose liner is installed in sheets or strips of various sizes by welding.

In all four processes, the desired microstructure in the corrosion resistant metal is often difficult to obtain without damaging the carbon steel backing or the joint of metal to carbon steel. Therefore, microstructures obtained must be evaluated from a corrosion viewpoint.

If metallurgical structures produced by these types of clad liners are not adequate to give the corrosion resistance expected, a loose heat-treatable liner may be necessary. Because the liner can never fit the carbon steel shell exactly, the use of internal pressure, necessitated by process conditions, can result in cyclic expansion and contraction of the liner to a degree depending upon the nature of the process. Even if the process is a constant pressure type, the liner will be subjected to cyclic operation every time the unit shuts down and starts.

Plastic strains introduced by these cyclic conditions can lead to various types of mechanical or corrosion fatigue failures or to stress corrosion cracking. Laboratory equipment designed to test metal endurance under accelerated cyclic conditions cannot reproduce plant operations exactly. However, any failures produced in laboratory equipment should be a warning of possible trouble ahead in the process unit.

Stress Corrosion Cracking in Various Alloys

The problem of stress corrosion cracking of metals is becoming increasingly serious. Stress corrosion cracking can occur across the grains of the material and along grain boundaries, as discussed above.

Figure 13 shows typical transgranular stress corrosion cracks produced in a stainless steel by attack of aqueous chloride solutions. At present, this phenomenon is poorly understood. Although chlorides are especially active in causing this cracking, other corrosive agents also may be important. For example, Monel, highly resistant to such cracking in presence of chlorides, may be prone to transgranular cracking in presence of hydrogen fluoride.

No method is known which can control transgranular cracking under all conditions. In any process, thorough laboratory and pilot plant testing is required with stressed specimens and actual process fluids to evaluate possible dangers from this type attack.

Effects of Hydrogen on Alloys

Other types of serious metallurgical failures can occur during operation of a unit. Possibility of these failures often is overlooked because they are not strictly caused by corrosion. The action of hydrogen upon steels is an example. At suitable elevated temperatures and pressures, hydrogen will react with carbon at the steel surface, removing the carbon and decarburizing the steel. If nothing else, this tends to reduce the steel's strength properties and to decrease the safety factor in design. Also, under suitable conditions, hydrogen will dissociate at the metal surface and diffuse into the steel in nascent form. This dissolved hydrogen may react with carbon inside the

steel to produce methane, which accumulates in grain boundaries until its pressure causes grain boundary fissuring. This effect is known as hydrogen attack. A decarburized, fissured structure is shown in Figure 14. The fissured material has lost much of its mechanical strength.

This type attack is well understood and can be prevented by use of appropriate low alloy steels, depending upon operating temperature and hydrogen partial pressure. Often these resistant alloys can be used at no additional cost because of the higher design stresses allowed for the alloy material in comparison with plain carbon steel.

Hydrogen attack can occur in carbon steels under what might appear to be mild conditions. For example, refractory liners often are depended upon to keep a vessel wall at a temperature low enough to avoid hydrogen attack. Failure of the lining material or bypassing of process fluids behind it can raise the metal wall temperature to a point where hydrogen attack can occur. Failures of important operating units in the refinery industry have occurred for this reason.

Hydrogen also can act in another manner to destroy metals, even though no corrosion loss can be noted. For example, if tantalum is held in certain media, it may become charged with dissolved hydrogen. This hydrogen does not react permanently with the tantalum (or with any impurity in the tantalum) as in the case of carbon steel. Rather, its mere presence in the microstructure decreases the ductility of tantalum to a negligible figure, thus making the metal susceptible to a brittle failure even at extremely low strains. Therefore, if hydrogen charging of metals is at all possible, physical tests of samples after corrosion testing should be made.

Records of Materials and Service Conditions

One important point which can easily be overlooked when evaluating alloys for new process equipment is the necessity of maintaining records of the chemical composition and heat treatment history of each corrosion specimen and of all fabrication procedures used in constructing both pilot plants and commercial units. It is embarrassing to find one specimen of an alloy with unusual corrosion resistance and be unable to determine which events in the sample's history contributed to its success. Also, construction of a unit based on test results with alloys having non-typical compositions or heat treatments can lead to catastrophic failures in plant equipment. With good records at hand plus the results of careful corrosion tests, exact alloy compositions, heat treatments and fabrication procedures can be specified for optimum corrosion resistance in the finished plant.

An alloy used for plant construction may tend to change its metallurgical structure with time under the process conditions to which it is subjected. This factor is frequently overlooked in literature data and in much laboratory work. In most cases, these structural changes are of no significance so far as corrosion resistance at the actual operation tem-

perature is concerned, but they can lead to serious corrosion during down times.

In all cases involving special heat treatments, it is advisable to work closely with metal or alloy producers. To be of any value, the heat treatment recommended must be completely practical and easily conducted in the field under adequate control but without special precautions or equipment. Metal producers know the industry and can be of great value in determining whether or not any given technique is practical.

Corrosion Monitoring in Process Equipment

Plant operating conditions can differ markedly from those used in the laboratory and pilot plant. Thus, corrosion evaluations should not end with construction of a new plant or unit. Provisions should be made during construction to install corrosion monitoring devices at sensitive locations throughout the plant. This is particularly important in chemical plants manufacturing products of high purity in which small amounts of corrosion products can cause product quality problems. Based upon accumulated monitoring data in the plant, various methods can be used to control any corrosion which appears. Process modifications sometimes are possible and may eliminate the problem. Corrosion inhibitors, anti-oxidants or other additives may be effective. As a last resort, it may be necessary to replace existing equipment with more resistant and usually much more expensive alloys. Corrosion monitoring data, combined with the pilot plant evaluations, are essential to a wise decision on this subject.

Corrosion monitoring in process equipment has been discussed in several earlier publications.[2,3,7] In general, two methods are available for monitoring purposes: corrosion coupons and electrical resistance corrosion probes. Understanding the relationship which these techniques bear to one another is important. Probes and coupons can be installed at almost any point in a process; both will measure accurately the actual corrosion rate on the metal specimen at the installation point. However, probes and coupons are best suited for obtaining different types of information, and any comprehensive corrosion monitoring program should make use of both techniques.

Corrosion probes are especially useful for direct *in situ* measurements of corrosion rates in operating plant equipment. Corrosion and fouling products formed on a probe usually have low electrical conductivities compared to the metal specimen. Therefore, the probe can be left in place and read regularly without removing the corrosion products and without interfering with normal unit operations. Sudden changes in corrosion rate caused by changes in stream composition or operating conditions can be detected almost immediately, before any appreciable damage is done to the unit. Corrective measures, such as the use of inhibitors, can be evaluated quickly and accurately without expensive shutdowns needed to handle corrosion coupons.

Retractable coupons, which can be inserted and removed through a gate valve, are available for these same uses. Because of the unavoidable errors introduced in cleaning and weighing small coupons, longer times are needed for corrosion rate determinations. Rapid changes are difficult or impossible to detect by this method.

Corrosion coupons, most useful for long-term observation of average corrosion rates, can be enclosed within a unit for inspection during shutdowns. With proper weight loss measurements and visual inspection, all effects of the corrosive environment can be observed, including general corrosion, pitting, intergranular attack, etc. Many alloys can be studied simultaneously, with heat treatments and fabrication procedures comparable to those practical for the unit in question. Hence, all of the corrosion experience accumulated in the laboratory and pilot plant can be checked under fullscale operating conditions. If serious corrosion should develop in a new unit, as indicated by probe data and if changes in stream composition and process variables cannot correct the difficulty, complete coupon data will be available on which to base selection of a more resistant alloy for corrosion control.

Summary

Selection of alloys for new process equipment is a complex procedure. Because of the many different effects that operating variables can have upon corrosion rates, laboratory and pilot plant corrosion evaluation programs should be designed carefully to cover all possible phases of plant operations. A careful metallurgical study should be made to determine the most desirable alloy compositions, heat treatments and fabrication procedures for the process. Finally, because laboratory and pilot plant tests never duplicate plant operation exactly, corrosion rates at sensitive locations should be monitored continuously so that any serious corrosion can be corrected before a structural or product-quality problem develops.

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DISCUSSIONS

Question by Robert W. Manuel, Socony Mobil Oil Co., New York City:

In the case of steel exposed to hydrogen at high temperature, it should be noted
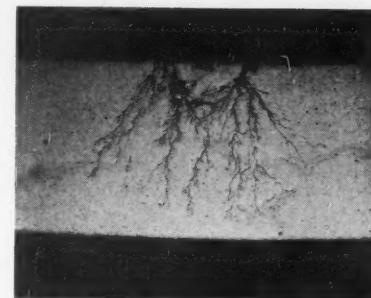
Figure 13—Transgranular attack on austenitic stainless steel shown at relatively low magnification. 25X, Glyceregia etch.
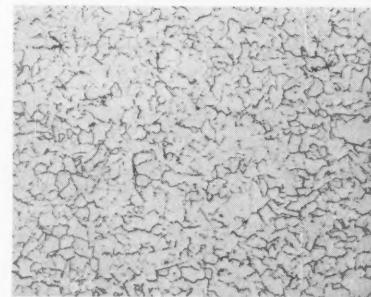
Figure 14—Structure of carbon steel after an exceptionally strong hydrogen attack. Black lines in the grain boundaries represent areas which were burst open by hydrogen and methane accumulating in the grain boundaries. 50X, Nital etch.

that permanent loss of ductility can occur before the advanced decarburization and microfissuring shown in the figure is observed—in fact before any damage is observable under the microscope. Concerning the example of intergranular precipitate in Hastelloy, I should like to ask which type Hastelloy this is and what corrosive medium can produce intergranular corrosion in Hastelloy.

Reply by E. S. Troscinski:

The alloy type is Hastelloy C. The corrosive medium in which intergranular corrosion of Hastelloy C may occur is impure acetic acid containing halides.

Question by Donald L. Burns, Gulf Oil Corp., Port Arthur, Texas:

The solutions of corrosion problems are complex and of course the complete evaluation of alloy materials is very important as you have shown. However, the economics of various methods must be considered. Does your company evaluate the use of corrosion inhibitors vs the use of these alloy materials for new units?

Reply by E. S. Troscinski:

If the problem of contamination by an inhibitor is unimportant, then it is considered as well as alloy materials. For the most part, economics govern the final choice. However, contingencies which sometimes arise with the use of inhibitors also must be considered.

Corrosion of Furnace Tubes
By Residual Welding Slag*

By KENNETH L. MOORE

About
the
Author

KENNETH L. MOORE is corrosion engineer at the Tidewater Oil Company refinery in Delaware City, Delaware. He did process design and corrosion work for three years with Atlantic Refining Company. He received a BS in chemical engineering and a BS in metallurgical engineering at the University of Michigan in 1954.

A CASE history of reforming furnace tube failure in a hydrogen plant is described in this article with the purpose of showing that proper precaution can prevent this type failure in other ethylene and hydrogen plants or in plants using high temperature processes.

Description of Process

At its Delaware refinery, Tidewater Oil Company built a hydrogen plant capable of producing 30 million standard cubic feet per day to provide hydrogen for treating 88,000 barrels per day of fuels and reformer charge stock from low gravity high sulfur crudes. The plant has two identical trains in parallel, each designed to produce 15 million cubic feet per day.

Hydrocarbon feed to the plant is LPG-grade propane, later changed to natural gas, which is thoroughly desulfurized to less than 1 part per million of sulfur. After pre-heating to 600 F, the hydrocarbon and steam enter the reforming furnace tubes. These vertical tubes are packed with nickel reforming catalyst which converts the hydrocarbon and steam into hydrogen, carbon dioxide and carbon monoxide. Subsequent equipment maximizes the hydrogen yield and purifies the product.

These reforming furnaces are different from many others in use; they are designed to operate at relatively high pressures of 120 to 150 psi. The tubes operate at a skin temperature of 1600 to 1700 F and outlet reaction gas temperatures of 1450 to 1500 F.

Details of Furnace

Divided into six cells, each furnace contains 180 vertical 30-foot tubes. Each cell has a row of 15 tubes on both major sides as shown in Figure 1. Initial material selection for these 5-inch OD tubes was a centrifugally cast 25 Cr-20 Ni stainless steel to resist the high temperatures and pressures, but procurement difficulties arose. Consequently, one furnace was constructed of extruded high nickel alloy tubes (34 Ni-21 Cr). This furnace is the primary subject discussed in this article.

The tubes were fabricated from two extruded 15-foot lengths. The circumferential weld which would be in the center of the firebox was made with a high nickel alloy welding rod (68 Ni-15 Cr). The root pass was deposited under inert gas, but subsequent passes were

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Abstract

Describes case history of severe and rapid corrosion of hydrogen reforming furnace tubes during high temperature operation. Attack was caused by presence of residual welding slag, sulfur and reducing conditions. Welding slag played a primary role in this corrosion. Explains repairs and modifications taken to correct the corrosion problem. Emphasizes that thorough sandblasting is essential for complete removal of welding slag and elimination of its associated corrosion problems.   3.7.3

made with a coated electrode. Welds were wire brushed after completion.

The furnace is a forced downdraft design with gas burners on top and on each minor side of all six cells. Burners use either refinery fuel gas or LPG-grade propane.

Description of Failure

After the catalyst tubes had been activated successfully at 1850 to 1900 F, the plant was put into service in September, 1957, and was inspected frequently to insure uniform and correct tube wall temperatures. There was every indication that operation was proper. However, after only three weeks' service, deposits developed rapidly on some tubes at the weld. Figure 2 shows the appearance of these incandescent growths while the furnace was in service.

Within three days after deposits were first seen, the furnace was shut down for inspection because of the speculated corrosion and possible hazards associated with release of high pressure hydrogen. Figure 3 shows the appearance of the deposits when cold. Figure 4 shows the attack under the deposits after the scale was removed by chipping and sandblasting. Figure 5 illustrates the attack where deposits had run down the tube.

Nature of Corrosive Attack

Attack by residual welding slag on the tubes was suspected because the corrosive attack was localized in the weld area. Emission spectrographic analysis determined the presence of calcium in the corrosion products, particularly at the interface with the metal. Welding rod flux would be the only source of this calcium.

A primary function of welding flux is to dissolve the oxide film from metal during welding. However, alloys derive their heat resistance from this oxide film. If this passive film cannot be maintained in service because of the presence of welding slag, uncontrolled attack can result with any high temperature alloy composition.

Investigation of welding slag residues' corrosivity showed that corrosive attack can be expected above temperatures from

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Figure 1—Plant layout of hydrogen plant reforming furnace.

FLUE GAS
TO WASTE
HEAT BOILER

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No 2
No 3
No 4
No 5
No 6

Figure 2—Corrosion deposits on furnace tubes as seen during operation.

1200 to 1300 F though certain slags are more corrosive than others.[1] The fluoride type fluxes are some of the most corrosive and are quite susceptible to absorption of sulfur in reducing atmospheres.

Corrosion products on the furnace tubes also were analyzed for sulfur, showing as much as 11 percent. Though the furnace was designed to operate with a flue gas containing no more than 30 grains of sulfur per 100 cubic feet, difficulties in the fuel gas diethanolamine (DEA) scrubbing system had resulted in much higher concentrations of H_2S in the fuel gas at the time of this severe tube corrosion. The furnace was fired for perhaps a full day with flue gas running as high as 260 grains of sulfur. Because of this high level, LPG-grade propane was used exclusively for fuel the next day.

The high cost of LPG as a fuel made it economically desirable to use refinery gas which had been scrubbed more effectively. After re-introduction of the refinery gas, the flue gas was between 122 and 166 grains of sulfur.

At the time of this fuel change, growths began to appear on the welds. After this development, the furnace was switched back to LPG and shut down after a day and a half.

The flue gas duct from each of the six cells was connected to a breeching which went to a waste heat boiler and draft fan. Because of the in-line arrangement (Figure 1), the Cell One had better draft than Cell Six. Measurements indicated that the draft varied from 0.4 to 0.1 inches of water going from Cells One to Six.

A high sulfur level can be particularly bad when coupled with reducing furnace conditions because H_2S in the fuel may not be oxidized and is more corrosive in this form than as SO_2. Residual slag also can accumulate sulfur from H_2S.

Combustion had been difficult in the cells with the least draft. Though flue gas had excess oxygen, indicating an oxidizing condition, localized smokiness in the cell would indicate local reducing conditions. Severity of corrosion in the cells was roughly in an inverse relationship to the draft. The most severe attack was in Cells Four, Five and Six.

Metallurgical examination of a damaged tube revealed that the attack was more severe than had been indicated after scale removal and sandblasting. Under the scale there was a dense, metal-like layer, shown in Figure 6. This phase was magnetic and slightly darker than the alloy. Analyses showed that 11.0 percent total sulfur was present in the form of chromous sulfide, iron chromium sulfide and nickel sulfide.

Figure 7 shows the sharp demarcation line between the altered phase and the metal. There was no indication of intergranular sulfidation as might be expected in high nickel alloys. The weld metal and parent metal were attacked and covered with the altered phase.

Examination of the tube metal away from the severely corroded weld area indicated slight corrosion—perhaps 2 mils at most.
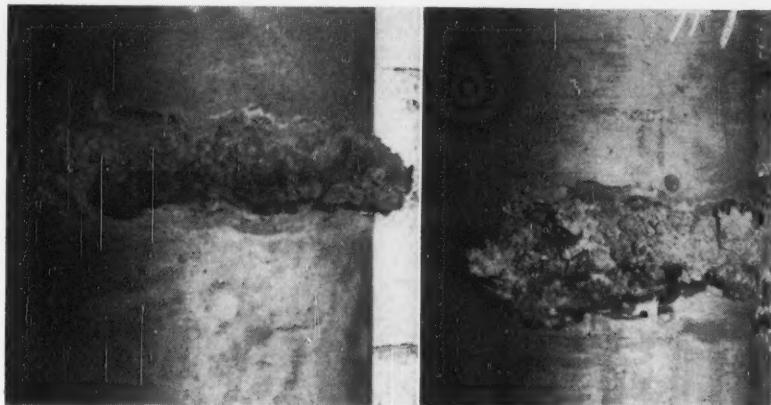
Figure 3—Corrosion deposits on two furnace tubes when cold in Cell Six.
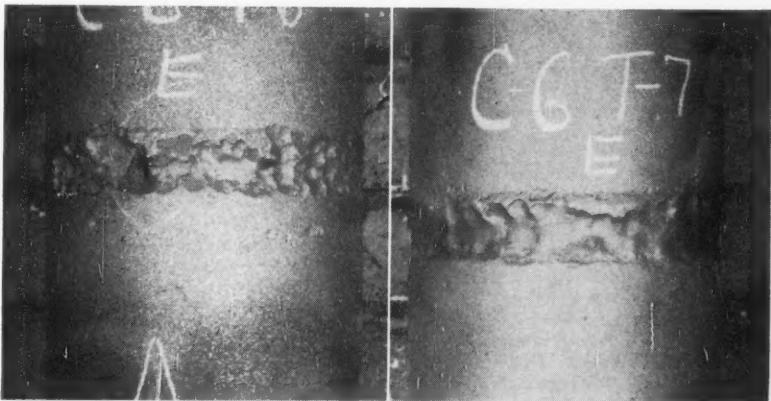
Figure 4—Two furnace tubes in Cell Six after chipping and sandblasting.
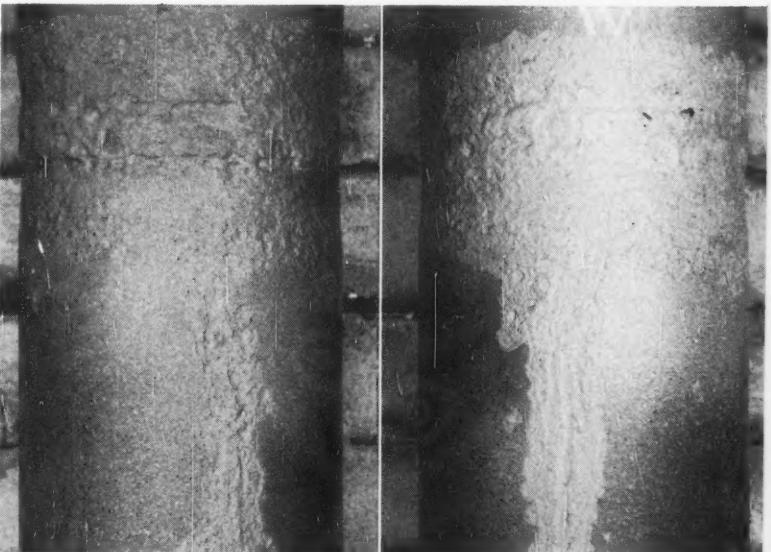
Figure 5—Two furnace tubes in Cell Four showing attack where deposits ran down from the weld area.

27t
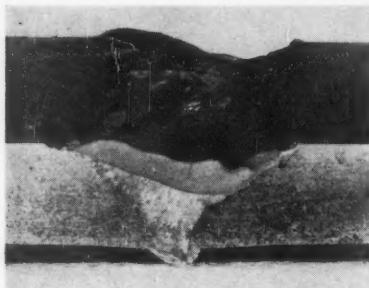
Figure 6—View of top surface and cross section of severely corroded furnace tube at weld.

Repairs and Modifications

Repairs were made to the corroded tubes by grinding out all the altered phase and re-welding with the original electrode. Complete removal of the altered phase was necessary because of its sulfur content and potential embrittling effect on new weld metal. Removal was checked visually and with sensitive magnets. The original welding rod was used to avoid mixing alloys. Inert gas welding with uncoated wire was not possible because of the tight quarters for these field welds.

Because of almost complete penetration by corrosion, some tubes were removed. The catalyst was unloaded and the tube cut at the weld, beveled and re-welded, starting with an inert gas root pass.

After re-welding, the surface was dressed with a grinding wheel. Then old and new welds were thoroughly sandblasted with fresh, clean sand to remove all traces of slag. Laboratory testing indicated that sandblasting was necessary to remove slag so that attack would not occur, even in oxidizing, low (or no) sulfur flue gas. Grinding alone was not considered adequate because it could smear slag into the metal surface.

Slag imbedded in pockets below the weld surface would not be deleterious because the flue gas would not be in contact with it.[1] Thus, complete slag removal from intermediate welding passes was not essential from a corrosion standpoint but was desirable from a weld quality standpoint.

The high sulfur condition in the refinery fuel gas was corrected after modifications in the DEA system. The gas is monitored more carefully now to avoid unknowingly firing it in critical furnaces.

Draft conditions were improved between cells by blocking part of the individual ducts leading to breeching with firebrick. Cell One had the most bricks because it was nearest the draft fan. Number of bricks in each duct was decreased uniformly with none in Cell Six.

After about two months' operation fol-
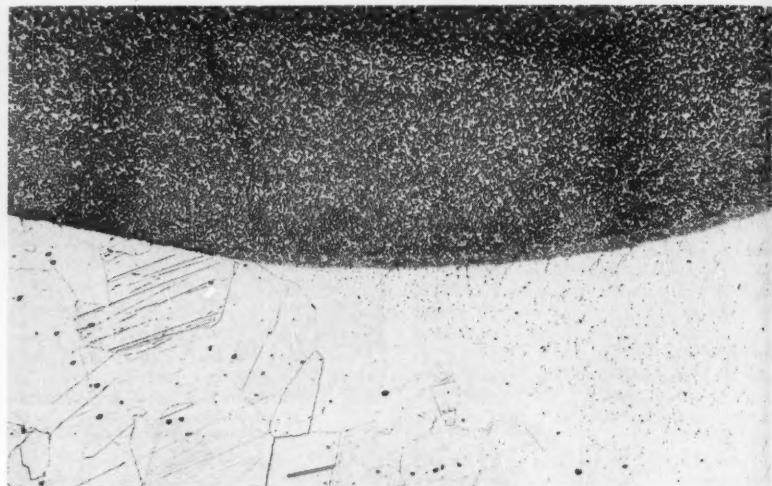
Figure 7—Photomicrograph of area at one side of corroded weld at intersection of parent metal (lower left), weld metal (lower right) and altered phase (top). 64X

lowing the repairs, several small spots developed on the tubes. The furnace was being examined as a precautionary measure when these spots were discovered. Identification of calcium in the corrosion product indicated that this minor attack was the result of weld splatter slag not removed earlier and slag at a few spots where the new weld metal had not been cleaned completely. The weld splatter must have been from the original welds because there had been complete shielding during the repair work.

The few spots in the new welds probably were areas of subsurface slag uncovered during the dressing operation but not removed by subsequent sandblasting. The questionable areas were ground out. The attack had not been deep enough to require re-welding except in a few areas.

Operation since this secondary inspection has been satisfactory. There is every reason to believe that a long service life can be obtained with the repaired tubes.

The furnace for the other train of the hydrogen plant was equipped with 25 Cr-20 Ni tubes as originally specified. Because of the tube failure in the first train, all welds were thoroughly sandblasted before the furnace was put in service. No difficulties have been encountered.

Summary

Catastrophic attack of 34 Ni-21 Cr furnace tubes was caused by the simultaneous presence of residual welding slag, sulfur and reducing conditions. Importance of the slag is supported by the following facts:

1. Base metal and weld metal were attacked in the same manner and degree where slag was present.

2. Base metal free of slag was not at-

tacked to any extent under the same high sulfur and reducing conditions existing at the areas of severe attack.

3. Minute slag particles from weld splatter and incomplete weld cleaning caused small areas of corrosion after the high sulfur and reducing conditions had been eliminated.

4. Laboratory tests confirmed that attack by welding slag can occur even though reducing conditions and sulfur are not present, though the rate is much lower.

For long service life, high sulfur and reducing conditions should be avoided even when residual welding slag is not present.

For immunity from high temperature corrosion by welding slag, it is necessary to (1) thoroughly sandblast welds and splattered areas or (2) weld with a bare wire and inert gas to avoid introduction of flux or (3) prove the slag is innocuous by testing at all possible operating conditions. Cleaning the welds by wire brushing or even grinding is not adequate when operating in the corrosive range, which can be as low as 1200 to 1300 F.

Acknowledgments

The author wishes to acknowledge the cooperation of C F Braun & Company and International Nickel Company, Inc., with Tidewater Oil Company. Their examinations, testing and assistance were sincerely appreciated. Special thanks are extended to G. R. Prescott of Braun & Company and to E. N. Skinner and G. R. Pease of International Nickel.

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NATIONAL ASSOCIATION
of CORROSION ENGINEERS

Acidproof Floor Construction With Membrane and Brick

A Report of NACE Technical Unit Committee T-6K on Corrosion Resistant Construction With Masonry and Allied Materials*

NACE TECHNICAL COMMITTEE REPORT

Publication 60—1

Introduction

THIS IS the second report prepared by Technical Unit Committee T-6K on Corrosion Resistant Construction with Masonry and Allied Materials. It is intended to supplement the first report on Acidproof Vessel Construction with Membrane and Brick Linings which was issued as Publication No. 57-6.[1] The comments in the first report pertaining to purpose, terminology, presentation and development history also apply to this report.

This report deals specifically with acidproof floor construction involving a chemical resistant masonry type facing joined throughout with a chemical resistant cement mortar applied over an impervious membrane on a suitable subfloor.

There are other types of acidproof floor construction such as thick asphalt mastic and filled resin toppings, with or without reinforcing, applied over a subfloor. These are generally lower in installed cost but also are generally less durable, particularly where severe service conditions and/or heavy traffic is involved.

Choice of type of floor construction and materials should depend upon the following factors: (1) type of traffic, (2) kind, amount and temperature of solutions or spillage expected, (3) personnel reactions, (4) maintenance and (5) ease of renewal. Acidproof brick floors are recognized as being the most economical type of construction where heavy traffic and severe corrosive conditions exist.

Important elements of acidproof brick floor construction are (1) subfloor or supporting structure, (2) impervious membrane over subfloor, (3) cement or mortar and (4) brick or tile facing. Discussion of these is given below.

Typical cross section details and application procedure for acidproof brick floors are shown in Figure 1. As illustrated, steps in the procedure are (1) cleaning floor, (2) applying primer, (3) applying first coat of asphalt membrane, (4) applying glass cloth reinforcement, (5) applying additional coats of asphalt

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membrane, (6) buttering brick with resin cement and (7) placing brick in place.

Failures of acidproof brick floors frequently result from flexing of subfloor, inadequate thickness of brick and inadequate pitch for drainage. Attention should be given to these items and to materials and workmanship when floors are installed.

Subfloors

It is fundamentally important to have a sound and rigid subfloor to support acidproof brick construction. Reinforced concrete is recommended for new floors. Steel subfloors are used infrequently and generally only where weight limitations prohibit use of concrete. Wood subfloors are considered unsatisfactory primarily because of movement problems.

Before flooring materials are applied, the subfloor should be examined, and any unsound or contaminated areas replaced. In the case of concrete, all damaged or questionable areas should be chipped out and replaced. Adequate floor slope for good drainage is important. Slope should be at least 3/16 inches and preferably ¼ inches per foot towards drains or trenches. Low spots should be avoided because finished floor will follow contour of subfloor.

Floor toppings of concrete are gen-

Abstract

Deals with acidproof floor construction involving a chemical resistant masonry type facing joined with a chemically resistant cement mortar applied over an impervious membrane on a suitable subfloor. Discusses factors determining the type floor construction required. Presents the steps in applying the brick construction including cleaning, priming, membrane coating and brick placement. 8.1.2

erally used to establish slope if changes are required. Care should be taken when applying concrete toppings including patch areas so that good bond is obtained between new material and the base slab. Floor slab and repaired area surfaces should have a smooth wood float finish in preference to a steel trowel finish to provide good adhesion of an asphalt type membrane. Concrete should be dry, clean and well cured before application of membrane is started.

Membranes

Impervious membranes are used to provide a chemical resistant barrier between subfloor and brick facing. Their use is considered necessary since the brick and mortar materials may be somewhat porous or discontinuous as applied with resulting leakage. The most commonly used membrane material is oxidized unfilled asphalt mastic (over 95 percent of applications). This material
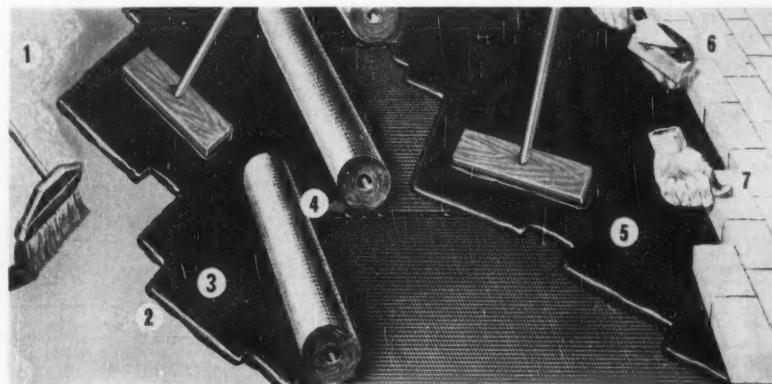

Figure 1—Steps in application of acidproof brick floors.

is generally reinforced with glass cloth in corners and over edges at trenches, etc., on the vertical surfaces of trenches and frequently on the flat surfaces of floors and trenches. The trend is towards reinforcement of mastic membranes on all surfaces to minimize movement and separation in the membrane.

Concrete subfloors, curbs, vertical surfaces, machine foundations, trench and sump pit sides and bottoms, etc., and any metal sub-surfaces which are to receive acidproof brick facings should be primed with an asphalt base material thinned with a petroleum solvent to brushing consistency. Asphalt content of primer should not be less than 35 percent by weight. In other respects the primer should conform to ASTM D-41. A sufficient quantity of primer should be used to provide thorough coverage, and the primer should be allowed to dry before applying the membrane material.

The matrix asphalt used to build up membrane should meet the requirements (ASTM D-5 Penetration of Bituminous Materials) given in Table 1.

Matrix asphalt should be heated to 250 to 400 F and applied to the primed surfaces with a squeegee. Multiple coat application should be made to thickness requirements; each coat should be inspected for blisters and pinholes. If present, they should be broken and filled before applying subsequent coats. A minimum thickness of 1/4 inch is recommended; 3/8-inch thickness is frequently used for heavy or severe service applications. A wooden straight edge should be used to insure a flat, smooth surface.

Asphalt-coated glass cloth is recommended for membrane reinforcement at corners, edges, etc. When used, the cloth should be applied following the first coat of asphalt and extended 3 to 6 inches onto the flat surfaces. Where glass cloth is used on flat surfaces, it should be overlapped at least two inches. Finished thickness of membrane is obtained by applying the subsequent coats of asphalt directly over the glass cloth reinforcement.

The principal exception to use of asphalt as the membrane is an installation where solvents are involved. In these cases a glass cloth reinforced resin membrane is used. A suitable primer should be applied on the subfloor to prevent reaction with the concrete if an acid catalyst or hardener is used with the resin materials.

Cement

Selection of cement mortar to be used for laying the brick depends primarily upon service conditions involved. Prin-

cipal cements used for bedding and jointing brick on floors are the furan resin, phenolic resin and sulphur base types. The chemical resistance of these is summarized in the NACE Publication No. 57-6.[1] The silicate type cements are seldom used because they are easily eroded by liquids and have poor resistance to water and solutions above 6 pH. Polyester resin base cements are used in some instances where resistance to sodium hypochlorite or chlorine dioxide is required.

Use of sulphur cement requires that poured joints be used. A bed joint is obtained by placing the brick on 1/4-inch spacing chips of cement and pouring the molten sulphur cement in the vertical joints so as to run under the brick. Care in application is necessary to avoid air locks and voids. Because of this difficulty with sulphur cement bed joints, frequently brick are laid directly on membrane.

Installation of brick in sulphur cement bonded floors should be started at the area's low point (adjacent to drains or trenches) and the bricks spaced to provide a uniform joint thickness of 1/4 inch. A 1/4-inch wooden strip generally is used in the longitudinal joints to provide accurate spacing. The pattern of brick should be common bond with the cross joints alternately in line. When a sufficient area has been laid, the molten sulphur cement should be poured into the joints, progressing from brick to brick. The first pour should be made to within 1/4 inch of the face of the brick, followed by a second pour to fill the joints with slight overpour. Interval between pours should be long enough to allow the original material to settle in the joint but short enough to permit the second pour to bond to the previously poured joints. Progressive joint length of several feet can generally be poured satisfactorily.

Where curbs and vertical protecting walls are involved, the vertical, cross and bed joints should be 1/4-inch thick. Bed joints should be formed by spacers. Faces of joints in vertical surfaces should be masked with paper or cloth to retain cement. Molten sulphur cement should be poured progressively into the cross

joints and back space of each course to a level about one-third of the brick thickness. Subsequent courses should be laid in a similar manner to complete vertical facing.

Use of resin cements permits conventional brick laying techniques to be used. Tilesetters' method is seldom used because of the uncertainty or difficulty of obtaining full thin joints in the thickness of brick desired for chemical resistant floors. Precaution should be taken to see that concrete and steel surfaces are completely primed and covered with membrane because most of the resin cements contain acid catalysts as hardening agents. Lack of priming barrier coat can result in neutralizing or weaking to such an extent that adequate setting of cement does not occur.

Installation should be laid by starting from one wall and working towards the opposite end. If long trenches are involved, it is generally desirable to start along edge of trench. The contact vertical edges of the brick should be buttered and the brick set directly on the asphalt membrane where bed joints are not used. Brick should be squeezed together to obtain joints approximately 1/8-inch wide; excess cement forced out of joint should be removed with a trowel. Where a bed joint is used, a thin layer of mortar, approximately 1/8-inch thickness, should be spread on top of the asphaltic membrane before laying the brick. The bricks are tapped as they are laid to level with adjacent brick and squeezed together to obtain proper width of joint. Brick in trenches and curbs are installed in a similar manner using buttered faces and tapping techniques to obtain full joints of the desired spacing.

Brick

Three basic types of industrial floors in which brick thickness varies depending upon severity of service are light duty, heavy duty and extra heavy duty.

Light duty construction, with 1 1/4-inch brick thickness, is used primarily where corrosive conditions are mild and there is little or no traffic. Use of grooved back brick or tile is generally considered undesirable; if used, the grooves should

TABLE 1—Matrix Asphalt Requirements

Melting point . . . . 200 to 220 F

Penetration Test

Degrees F	Grams	Seconds	
115	50	5	less than 70
77	100	5	35–45
32	200	60	25–35

Bitumen soluble in CS_2 . . . . not less than 90%

Weight . . . . 65–75 lb/cu ft

TABLE 2—Brick Sizes and Amount of Materials Required Per Square Foot

Type of Floor	Brick Thickness (Inches)	Size of Brick (Inches)	Width of Vertical Joints (Inches)	Per Square Foot		
				No. of Brick	Resin Based Cement (Lb)	Sulphur Based Cement (Lb)
Light Duty	1 1/2	12 x 6 x 1 1/2	1/4	1.89	. . .	1.29
	1 1/2	12 x 6 x 1 1/2	1/8	1.94	0.39	. . .
	1 3/8	8 1/4 x 4 x 1 3/8	1/4	4.00	. . .	1.70
	1 3/8	8 1/4 x 4 x 1 3/8	1/8	4.17	0.52	. . .
	1 3/8	8 x 3 3/4 x 1 3/8	1/4	4.37	. . .	1.46
	1 3/8	8 x 3 3/4 x 1 3/8	1/8	4.58	0.45	. . .
Heavy Duty	2 1/4	8 x 3 3/4 x 2 1/4	1/4	4.37	. . .	2.92
	2 1/4	8 x 3 3/4 x 2 1/4	1/8	4.58	0.90	. . .
	2 1/2	9 x 4 1/2 x 2 1/2	1/4	3.28	. . .	2.79
	2 1/2	9 x 4 1/2 x 2 1/2	1/8	3.42	0.85	. . .
Extra Heavy Duty	3 3/4	8 x 3 3/4 x 4 1/2	1/4	3.68	. . .	4.37
	3 3/4	8 x 3 3/4 x 4 1/2	1/8	3.84	1.33	. . .

Asphaltic primer coverage is 0.01 gal. per square foot.
Asphaltic membrane at 1/4 in. thickness is 1.5 lb per square foot.
Above figures are based on average practice.
Quantities may vary, depending upon individual conditions, at the job.
Excess waste and irregular brick require additional material.

1/4 in. bedjoint requires 3.58 lb sulphur based cement per sq. ft.
1/8 in. bedjoint requires 1.05 lb carbon filled resin based cement per sq. ft.

be filled with cement mortar before tile are laid. This thickness generally is considered to be inadequate for chemical plant floors.

Heavy duty construction, with 2½-inch brick thickness, is used where chemical exposures are severe and traffic is moderate, including light lift trucks.

Extra heavy duty construction, with 3¾-inch brick thickness, is used where heavy traffic and impact loading may be involved. Sizes of the brick shapes generally used and the amount of materials required per square foot of floor for typical construction is summarized in Table 2.

Costs

Installed cost of this type floor construction varies with area size, materials, installation details and location. A general estimate can be made for installed cost at $2 per square foot for light and heavy duty construction and $2.75 per square foot for extra heavy duty construction. These figures are for areas of 2000 square feet and larger. They include primer, asphalt mastic membrane and fireclay brick laid and bedded in resin cement mortar. If bed joint is not used, cost will be reduced approximately 30 cents per square foot for resin cements and 20 cents per square foot for sulphur cements. Use of sulphur cement in place of resin cement may reduce cost about 5 percent. Use of shale brick in place of fireclay brick may reduce cost about 5 percent.

Reference

1. Acidproof Vessel Construction With Membrane and Brick Linings. Report of NACE Technical Unit Committee T-6K on Corrosion Resistant Construction With Masonry and Allied Materials. *Corrosion*, **13**, 195t-204t (1957) March.

Translations of Foreign Terms
On Corrosion of Metals*

Preface

THE ATTACHED table, giving definitions of corrosion terms in English, French, German and Russian was sent to Paul Delahay, Louisiana State University, Baton Rouge, La., chairman of the subcommittee on foreign relations of the Inter Society Corrosion Committee by Prof. G. Schikorr, Chemische Landesuntersuchungsanstalt, Stuttgart, Germany. Dr. Schikorr, a German representative on the ISCC subcommittee on foreign relations, has long been active in corrosion investigations in his own country and has an enviable international reputation for his work.

As an appendix to the table, and for the reasons given in the appendix, a separate table is added to the reprinted information, defining some of the differences in the meanings of the terms as they are understood in the United States.

It is believed that these definitions will be useful to investigators who find valuable reports of corrosion control work in languages other than their own and who need a precise understanding of the terms used.

Credit for this work is due to U. R. Evans, University of Cambridge, England, who compiled the English version; Centre Belge d'Etude de la Corrosion, Brussels, whose workers compiled the French version; W. Meister, Leiter des Amtes fur Standardisierung der Deutschen Demokratischen Republik, who compiled the Russian version. R. B. Mears, United States Steel Corp., Monroeville, Pa. and his co-workers supplied the terms included in the appendix. There is an inherent difficulty in reviewing translations of this kind because definitions used for similar terms differ from nation to nation. For instance, Items 1.23 and 1.231 define a corrosion cell and a local cell, respectively. Such a differentiation is not made in the United States. The definition in the "Corrosion Handbook" edited by H. H. Uhlig (John Wiley & Sons, Inc., N. Y.) states: Local Cell. A cell, the emf of which is due to differences of potential between areas on a metallic surface in an electrolyte. There is no reference to size of areas as in Item 1.231.

Another discrepancy between German and American terminology becomes apparent in Items 1.24, 1.241 and 1.26. The first item defines corrosion of a metal

Abstract

A table is given in which terms commonly used to describe corrosion control work are arranged according to like meaning in German, English, French and Russian. An appendix lists some definitions and meanings which differ from those in the table according to the understanding of their meaning in the United States.   1.4

with other materials including non-metals. In the second instance, corrosion is limited only to metals in conductive liquids. The last definition describes crevice corrosion as occurring in crevices that are present in the metal itself or formed by contact with other objects. American terminology makes no such distinction. The "Corrosion Handbook" defines: Contact Corrosion (Crevice Corrosion). Corrosion of a metal at an area where contact is made with a material usually non-metallic.

The following suggestions concerning the English translation are based mainly on the terminology used in the United States; the Russian translations on terminology used in G. V. Akimov's book, "Theory and Research Methods of Metallic Corrosion" (Publishing House of the USSR Academy of Science, Moscow, 1945).

Fremdsprachige Übersetzung der Begriffe

Abschnitt *)	deutsch	englisch	französisch	russisch
1	**Allgemeine Begriffe**	**General Terms**	**Termes Généraux**	**Общие термины**
1.1	**Korrosion**	**corrosion**	**corrosion**	**коррозия**
1.2	**Elektrochemische Korrosionsbegriffe**	**electrochemical corrosion terms**	**termes de corrosion électrochimique**	**термины, относящиеся к электрохимической коррозии**
1.21	Elektrochemische Korrosionstheorie	electrochemical corrosion theory	théorie de la corrosion électrochimique	теория электрохимической коррозии
1.22	Veredelung bzw. Verunedelung des Potentials	shift towards a more noble (or less noble) potential	anoblissement ou avilissement de potentiel	улучшение или ухудшение потенциала
1.23	Korrosionselement	corrosion cell	pile de corrosion	коррозионный элемент
1.231	Lokalelement	local cell	pile locale	местный элемент
1.24	Berührungskorrosion	crevice corrosion, at a contact with non-metallic material	corrosion par contact	коррозия соприкосновения
1.241	Kontaktkorrosion	corrosion at a contact with a second metal	corrosion par contact	контактная коррозия
1.25	Fernschutzwirkung	cathodic protection	action protectrice à distance	дистанционное защитное действие
1.26	Spaltkorrosion	crevice corrosion	corrosion dans les fissures	щелевая коррозия
1.27	Fremdströme, Irrströme (vagabundierende Ströme)	current from external sources, stray currents	courants vagabonds	блуждающие токи

*) Die Abschnitte beziehen sich auf DIN 50 900.

Abschnitt *)	deutsch	englisch	französisch	russisch
1.3	Korrosionserscheinungen	corrosion phenomena on the metal	formes de corrosion des métaux	явления коррозии в металлах
1.31	Ebenmäßiger Angriff	uniform attack	attaque uniforme	равномерная коррозия
1.32	Lochfraß	pit	piqûre	коррозионная язва
1.33	Narbe	saucer-shaped pit, scar	balafre	коррозия пятнами
1.34	Durchlöcherung	perforation	percement	сквозная коррозия
1.35	Interkristalline Korrosion, Korngrenzenkorrosion	intercrystalline corrosion, intergranular corrosion	corrosion intercristalline, corrosion à la limite des grains	межкристаллитная коррозия, коррозия по границам зерен
1.36	Transkristalline (intrakristalline) Korrosion	transcrystalline (intracrystalline) corrosion	corrosion transcristalline (intracristalline)	транскристаллитная (интракристаллитная) коррозия
1.37	Selektive Korrosion	selective corrosion	corrosion sélective	избирательная коррозия
1.38	Schichtkorrosion	layer-corrosion	corrosion en strates, corrosion feuille tante, corrosion ex foliente	слоевая коррозия
1.4	Sonstige allgemeine Begriffe	further general terms	autres termes généraux	прочие общие термины
1.41	Passivität	passivity	passivité	пассивность
1.42	Schutzschicht	protective layer	couche protectrice	защитный слой
1.43	Anlaufen	tarnishing [1]), heat-tinting [2])	ternissement, voilage	побежалость
1.44	Beizen	pickling	décapage	травление
1.45	Inhibitor, Hemmstoff	inhibitor	inhibiteur	ингибитор, замедлитель коррозии
2	Besondere Begriffe	Special Terms	Termes Particuliers	Специальные термины
2.1	Korrosion unter Wasserstoffentwicklung	hydrogen-evolution type of corrosion	corrosion avec dégagement d'hydrogène	коррозия с выделением водорода
2.11	Beizsprödigkeit	embrittlement caused by pickling	fragilité de décapage	хрупкость от травления
2.12	Beizblasen	blistering caused by pickling	soufflures de décapage	пузыри от травления
2.13	Sparbeizzusatz	pickling inhibitor	économiseur de décapage	присадка к протраве
2.14	Sparbeize	pickling bath containing an inhibitor	décapant avec économiseur	протрава с присадкой
2.2	Korrosion unter Sauerstoffverbrauch	oxygen-consumption type of corrosion	corrosion avec consommation d'oxygène	коррозия с потреблением кислорода
2.21	Unterschiedliche (differentielle) Belüftung	differential aeration	aération différentielle	неодинаковый (дифференциальный) доступ воздуха
2.211	Belüftungselement	differential aeration cell	pile d'aération différentielle	элемент доступа воздуха
2.22	Schwitzwasserkorrosion	corrosion by condensation of moisture	corrosion par eau de condensation	коррозия от конденсатной воды
2.23	Rost	rust	rouille	ржавчина
2.231	Flugrost	—	—	налет ржавчины
2.232	Fremdrost	rust from external sources	rouille erratique, rouille pérégrine	чужая ржавчина

[1]) wenn in unreiner Luft bei normaler Temperatur erzeugt
[2]) wenn bei erhöhter Temperatur erzeugt

Abschnitt *)	deutsch	englisch	französisch	russisch
2.24	Weißer Rost	white rust	rouille blanche	белая ржавчина
2.25	Nichtrostender Stahl	stainless steel	acier inoxydable	нержавеющая сталь
2.26	Spongiose (Graphitierung)	graphitization	graphitisation	шпангиоз (графитрирование)
2.27	Grünspan	verdigris	vert-de-gris	яд-медянка (основная уксуснокислая медь)
2.28	Patina	patina	patine	патина
2.29	Entzinkung	dezincification	dézincification	коррозия цинка в латуни
2.3	**Verzunderung**	**high temperature scaling**	**écaillage**	**образование окалины**
2.31	Hitzebeständigkeit	heat-resistivity	résistance à la chaleur	жаростойкость
2.32	Zunder	scale	écaille (calamine)	окалина
2.321	Zunderausblühungen	—	écaillage	выцветы окалины
2.322	Schwefelpocken	sulphur pockmarks	pustules sulfureuses	серная оспа
2.33	Wasserdampfspaltung	decomposition of water-vapor	décomposition de vapeur d'eau	расщепление водяного пара
2.34	Wasserstoffkrankheit des Kupfers	hydrogen-embrittlement of copper	fragilité l'hydrogène du cuivre	водородная болезнь меди
2.4	**Korrosion unter gleichzeitiger mechanischer Beanspruchung**	**corrosion under mechanical stress**	**corrosion sous contrainte mécanique simultanée**	**коррозия при одновременной механической нагрузке**
2.41	Spannungskorrosion	stress corrosion	corrosion sous tension	коррозия под напряжением
2.42	Interkristalliner Riß, Korngrenzriß	intercrystalline crack	fissure inter-cristalline, fissure aux joints de grains	межкристаллитная трещина, интеркристаллитная трещина
2.43	Transkristalliner Riß (intrakristalliner Riß)	transcrystalline crack	fissure trans-cristalline (fissure intracristalline)	транскристаллитная (интракристаллитная трещина)
2.44	Reiboxydation	fretting corrosion	oxydation par frottement	окисление при трении
2.441	Bluten	—	saignement, saignée	кровоточение
2.45	Korrosionsermüdung	corrosion fatigue	fatigue sous corrosion	коррозионная усталость
3	**Korrosionsprüfung**	**Corrosion Testing**	**Essais de Corrosion**	**Коррозионные испытания**
3.1	**Prüfungsarten**	**methods of testing**	**sortes d'essais**	**виды испытаний**
3.11	Prüfung	testing	essai	испытание
3.12	Laboratoriums-versuch	laboratory test	essai de laboratoire	лабораторное испытание
3.121	Dauertauchversuch	total immersion test	essai par immersion complète	длительное испытание при погружении
3.122	Rührversuch	stirring test	essai avec agitation	испытание при погружении в перемешивной агрессивной среде
3.123	Wechseltauchversuch	alternate immersion test	essai par immersion et émersions alternée	испытание при переменном погружении
3.124	Durchflußversuch	continous flow test	essai avec circulation	проточное испытание
3.125	Feuchtlagerversuch	high humidity and condensation test	essai de stockage humide	испытание при хранении на влажном воздухе

Abschnitt *)	deutsch	englisch	französisch	russisch
3.126	Sprühversuch	(salt-)spray test	essai au brouillard salin	испытание при разбрызгивании
3.127	Kochversuch	corrosion test in boiling liquids	essai à l'ébullition	испытание при кипячении
3.128	Dampfversuch	steam test	essai à la vapeur	испытание в водяном паре
3.129	Druckgefäßversuch	test at pressures above atmospheric	essai à l'autoclave	испытание в напорном сосуде
3.13	Naturversuch	field-test	essai naturel	испытание в естественных условиях
3.131	Bodenkorrosionsversuch	soil corrosion test	essai de corrosion édaphique	испытание на почвенную коррозию
3.14	Schnellkorrosionsversuch	accelerated corrosion test	essai de corrosion accélérée	ускоренное испытание на коррозию
3.15	Kurzzeitversuch	test of short duration	essai de corrosion de courte durée	краткосрочное испытание
3.16	Langzeitversuch	test of long duration	essai de corrosion de longue durée	длительное испытание
3.2	**Probenarten**	**types of specimen**	**sortes d'échantillons**	**виды образцов**
3.21	Prüfstück	object submitted for test	échantillon	испытуемая деталь
3.22	Probe	test specimen test bar	éprouvette	образец
3.23	Hebelprobe	lever-test bar	éprouvette élastique	рычажный образец
3.24	Bügelprobe Gabelprobe Schlaufenprobe	— fork-test bar loop-test bar	éprouvette en étrier éprouvette en fourche eprouvette en boucle	скобообразный образец вилкообразный образец петлеобразный образец
3.3	**Prüfungsflüssigkeiten**	**test solutions**	**liquides d'essai**	**жидкости для испытаний**
3.31	Destilliertes Wasser	distilled water	eau distillée	дестиллированная вода
3.32	Modellösung	standardized test solution'	solution type	модельный раствор
3.321	Künstliches Meerwasser	artificial seawater	eau de mer artificielle	искусственная морская вода
3.322	Oxydische Kochsalzlösung	sodium chloride solution containing hydrogen peroxide	solution de chlorure de sodium oxydante	оксидный раствор поваренной соли
3.33	Ferroxyl-Indikator	ferroxyl indicator	indicateur ferroxyle	ферроксильный индикатор

Appendix—Some American Definitions of Foreign Corrosion Terms

Item	Language	Suggested Translation
1.23	Russian	ЭЛЕКТРОХИМИЧЕСКАЯ (КОРРОЗИОННАЯ) ПАРА
1.24	English	Corrosion due to contact with other (also non-metallic) materials
1.241	French	Corrosion par contact en présence de liquides
1.25	French	Protection cathodique
1.25	Russian	КАТОДНОЕ ЗАЩИТНОЕ ДЕЙСТВИЕ

Appendix (Continued)—Some American Definitions of Foreign Corrosion Terms

Item	Language	Suggested Translation
1.32	Russian	ПИТТИНГ
1.33	Russian	РУБЕЦ
1.43	Russian	ПОТУСКНЕНИЕ МЕТАЛЛА
2.13	Russian	ИНГИБИТОР
2.14	Russian	ПРОТРАВА С ИНГИБИТОРОМ
2.21	Russian	ДИФФЕРЕНЦИАЛЬНАЯ АЭРАЦИЯ
2.211	Russian	ПАРА ДИФФЕРЕНЦИАЛЬНОЙ АЭРАЦИИ
2.26	Russian	ГРАФИТИЗАЦИЯ
2.29	Russian	ОБЕСЦИНКОВАНИЕ ЛАТУНИ
2.31	Russian	ТЕРМОСТОЙКОСТЬ
2.34	Russian	ВОДОРОДНАЯ ХРУПКОСТЬ
3.1	Russian	МЕТОДЫ ИСПЫТАНИЯ
3.121	English	Stagnant immersion test
3.121	French	Essai par immersion (sans agitation)
3.122	English	Agitated immersion test
3.122	Russian	ИСПЫТАНИЯ ПРИ ПЕРЕМЕШИВАНИИ
3.129	English	Autoclave test
3.131	French	Essai de corrosion dans le sol
3.15	English	Short-time test
3.16	English	Long-time test
3.23	English	Cantilever beam specimen
3.24	English	Buegelprobe = Horseshoe specimen or U-bend specimen

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HOW CORROSION IS INDEXED

1. Alphabetical subject and author indexes are published in December at the end of the calendar year volume of 12 issues.
2. Abstracts of articles appear in the Corrosion Abstracts section of COR-ROSION.
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6. CORROSION will be indexed, beginning in January 1959 by Applied Science and Technology Index.
7. A 10-year alphabetical subject and author index (1945-54) has been published and is available for sale.

Evaluation and Improvement of Methods for

Detecting Intergranular Corrosion Susceptibility in Aluminum Alloys*

By SARA J. KETCHAM and WALTER BECK

Introduction

SUSCEPTIBILITY TO intergranular corrosion in aluminum alloys used for structural aircraft applications is a potential source of service failures upon exposure to stress and corrosive environments. Because improper heat treatment procedures are held responsible for the susceptibility, inspection tests are conducted subsequently to heat treatment. The most widely used test method is a 6-hour immersion in a NaCl-H₂O₂ solution, required by the military specification concerning heat treatment of aluminum alloys.[1]

However, considerable evidence indicates that this method is not sensitive enough for Al-Zn alloys, particularly 7075, which is used for integrally stiffened wing construction in current airplane designs. Information available on the subject is contradictory, the method being reported as satisfactory in some cases, but in others as relatively insensitive.

The work described in this article was instigated by the Bureau of Aeronautics to determine the reason for these contradictions and to develop, if possible, a more sensitive method for detecting intergranular corrosion susceptibility in 7075-T6 aluminum alloy.

Experimental Procedure

Material and Heat Treatment

Alloy 7075-T6, 0.064 inches thick, was used for the experimental work. Sheets were sheared into 3-inch by 10-inch panels, solution heat treated at 493 C for 30 minutes, quenched in water and then aged at 121 C for 24 hours. Temperature of the quenching water was varied. One set was quenched in boiling water, one in cold water (21 C.) and the third in water at 66 C. Tensile, yield and elongation values were obtained for each set and susceptibility to intergranular corrosion determined by the NaCl-H₂O₂, 6-hour test.

Preparation of Specimens

All specimens were degreased, immersed 1 minute in a solution containing 5 percent HNO₃, 0.5 percent HF, rinsed, immersed in concentrated HNO₃ for 1 minute, rinsed in distilled water and dried in acetone.

Testing Methods

Solutions used for investigating susceptibility to intergranular corrosion included 1N NaCl without and with addition of HCl and H₂O₂. A solution also was used containing K₂Cr₂O₇, NaCl and CrO₃, which is often used in stress corrosion testing of aluminum alloys. The electrolytic method consisted of making the specimens anodic in various dilute acids and in NaOH and NaCl solutions. These screening experiments were performed on material known to be susceptible to intergranular corrosion.

The procedures most effective in detecting intergranular corrosion susceptibility were the 6-hour immersion in a solution of 1N NaCl with 0.3 percent H₂O₂ and the electrolytic method with 1N NaCl as the electrolyte. These methods, therefore, were investigated in greater detail.

Study of the NaCl-H₂O₂ Method

Because decomposition rate of H₂O₂ was considered the most important variable, change of concentration of H₂O₂ during the 6-hour test period was determined by titration with permanganate. This experiment was made at three temperatures: 26C, 35C and 41C. The resultant effects on specimens susceptible to intergranular corrosion were determined metallographically.

In addition, a few experiments were made changing the NaCl concentration but maintaining the concentration of 0.3

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Abstract

Present methods for determining susceptibility to intergranular corrosion in aluminum-zinc alloys were considered inadequate and attempts were made to improve or refine them. NaCl-H₂O₂ and electrolytic tests and modifications were studied. Results obtained with electrolytic method showed good correlation with results of NaCl-H₂O₂ test. The latter is believed to be more sensitive under optimum conditions, but the variables inherent in the use of H₂O₂ are difficult to control. Electrochemical processes by which the various methods accelerate intergranular corrosion are discussed. Modification of the present inspection method is recommended, and a quantitative method for assessing degree of severity of intergranular penetration suggested.
2.3.5

percent H₂O₂. Experiments were made on sensitive material for 1 hour and 6 hours in 0.01N and 1N NaCl both with 0.3 percent H₂O₂. In another group of experiments, using 1N NaCl, the concentration of H₂O₂ was increased to 0.6 percent. In all experiments, the volume to area ratio was kept constant at 30 ml of solution per square inch as required by specification.[1]

Study of the Electrolytic Method

1N NaCl was selected as the most satisfactory electrolyte because, in the majority of the solutions tried, a constant current could not be maintained. Specimens, 5 inches by 1 inch by 0.064 inches, were then prepared from improperly heat treated material, 1 inch of each used for the NaCl-H₂O₂ test and the remaining 4 inches for the electrolytic test. The amount of attack that occurred on the portions used for the NaCl-H₂O₂ test was taken as a standard, and time and current density varied until a similar amount of attack occurred on the material from the same specimens during the electrolytic test. The most satisfactory combination of current density and time appeared to be 0.065 amps per sq. in. for 20 minutes. With these conditions, a large number of specimens representing the three quenching rates were subjected to the NaCl-H₂O₂ and the electrolytic methods to ascertain the degree of correlation obtainable between the two techniques. Corrosion experiments also were conducted on 2024-T3 aluminum alloy.
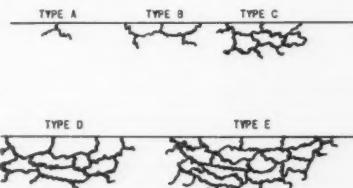

Figure 1—Illustrations of severity of attack. Sample report: 3 areas B, 2 areas C, 1 area D. 154X.
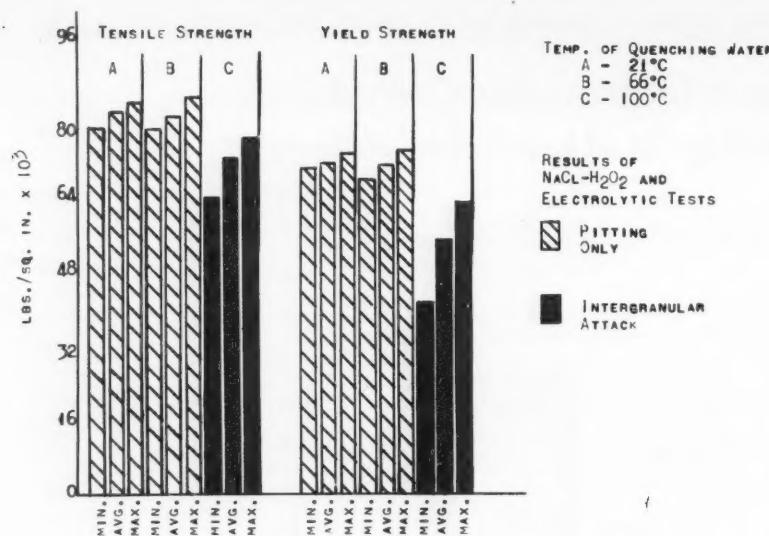
Figure 2—Effect of quenching rate on mechanical properties and corrosion of 7075-T6.

Figure 3—Decomposition of H_2O_2 in presence of corroding specimen. Initial concentration was 0.3 percent in 1N NaCl.

Figure 4—Effect of temperature on severity of intergranular attack in NaCl-H_2O_2 solution, 6-hour immersion. Maximum depth of penetration for the three temperatures: 26 C: 16×10^{-4} in., 35 C: 19×10^{-4} in., 41 C: 20×10^{-4} in.

Metallographic Technique

Subsequent to the corrosion experiments, corrosion products were removed from the specimens by immersion in 2 percent CrO_3-5 percent H_3PO_4 (both by weight) solution at 88 C for 10 minutes. In all cases, the edge polished for examination was cut after the corrosion tests.

Method for Comparative Evaluations of Intergranular Corrosion

Severity of intergranular attack was evaluated by a procedure developed by the Douglas Aircraft Company for control of aluminum heat treatment.[2] Areas of severity from A to E based on depth and width of intergranular attack were established (Figure 1) and the number of each type of area counted over a certain specimen length, in this case, 0.5 in. The maximum depth of penetration also was recorded. If attack was relatively continuous, the length of each area of one severity also was measured. The examination is conducted at a magnification of 500 diameters.

Experimental Results

Effect of Quenching Rate on Mechanical Properties and Susceptibility to Intergranular Corrosion

Results obtained on 40 tensile specimens are shown in Figure 2. Only tensile and yield strength were plotted because elongation values showed no sensitivity to quenching rate. The minimum, maximum and average value obtained on the 40 specimens are shown. The boiling water quenched specimens fell below the specification requirements and showed intergranular corrosion attack.

NaCl-H_2O_2 Experiments

The change of concentration of H_2O_2 and temperature effect on H_2O_2 decomposition is given in Figure 3. At room temperature, within the first 3 hours, H_2O_2 concentration has decreased by 24 percent, in the last 3 hours by 12 percent,

making a total decomposition over the test period of 36 percent. With increasing temperature, H_2O_2 decomposition increased.

The effect of temperature on intergranular attack is shown in Figure 4. The number of areas of each degree of attack were counted and plotted. The number of each type increased with increasing temperature.

In Figure 5, average percent decomposition of H_2O_2 is plotted, determined by graphic integration of the curves in Figure 3. Also shown are maximum depth of intergranular penetration and total number of attack areas, against increasing temperature. These curves show that increasing temperature accelerates H_2O_2 decomposition rate and intensifies intergranular attack. It is believed that local cell currents also increase with increasing temperature and that would also result in intensified intergranular attack.

NaCl concentration had an effect as shown in Figure 6. The depth of attack was approximately the same in 0.01N and 1N, but the width of the grain boundary attack increased with increasing NaCl concentration. Experimental analysis showed that at the lower chloride anion concentration the rate of H_2O_2 decomposition was slower than at the higher concentration. Therefore, the greater attack intensity in 1N NaCl can be attributed not only to higher conductivity but perhaps also to the increased concentration effect of chloride anions, resulting in a faster H_2O_2 decomposition rate. Raising the H_2O_2 content from 0.3 percent to 0.6 percent in 1N NaCl had no significant effect in increasing attack.

Electrolytic Method

The electrolytic test revealed intergranular susceptibility in improperly heat treated material but also caused the strange type of attack pictured in Figure 7 (the possibility that poor polishing technique was responsible for this was
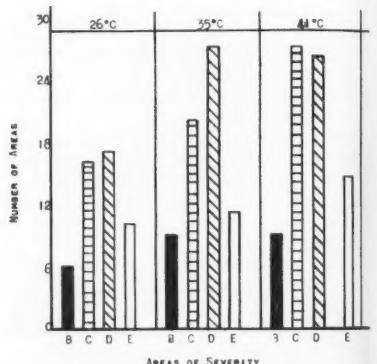
investigated and discounted). The extent of this attack increased with increasing current density and time, but current density had a stronger effect than time. The attack in Figure 7 was produced by applying 0.5 amp per square inch for 3 minutes.

The effect of increasing current density while maintaining time constant is shown in Figure 8. Specimens used were cut from the same 3-inch by 10-inch panel. Depth of attack did not increase perceptibly with increase of current density, but localized attack increased with removal of whole grains finally occurring. At the higher current densities, therefore, it is difficult to detect the intergranular nature of the attack, but the NaCl-H_2O_2 test on the same material verified the assumption that the attack was intergranular. Figure 9 shows the effect of maintaining the current density at a lower value (0.065 amp per sq. in.) and increasing the time. In this case, depth of attack did increase and localized attack did not. Application of this current density for 20 minutes was chosen as optimum test conditions because it excluded the masking effect exerted by higher current densities.

When the NaCl-H_2O_2 test and the electrolytic method were used on samples from the same panel, excellent correlation was obtained. Both tests revealed intergranular attack in sensitive material and caused only pitting attack on insensitive material. Depth of attack was always about the same, but NaCl-H_2O_2
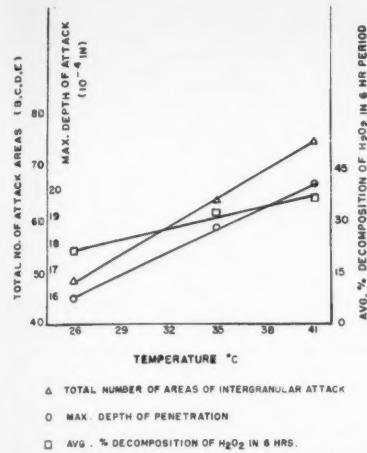
Figure 5—Summary of temperature effect on NaCl-H₂O₂ test.

△ TOTAL NUMBER OF AREAS OF INTERGRANULAR ATTACK

O MAX. DEPTH OF PENETRATION

□ AVG. % DECOMPOSITION OF H₂O₂ IN 6 HRS.
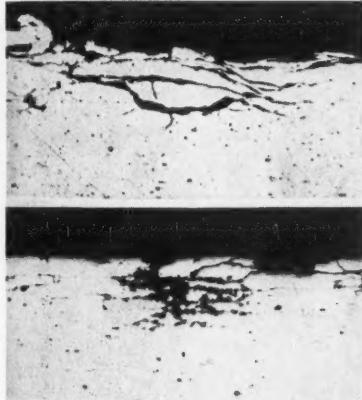
Figure 6—Effect of NaCl concentration on intergranular attack. Immersed 6 hours. Top section: 1 N NaCl with 0.3 percent H₂O₂; bottom section: 0.01 N NaCl with 0.3 percent H₂O₂. 119X.


Figure 7—Appearance of attack on anode in electrolytic test regardless of quenching rate. Electrolyte was 1 N NaCl. Current was 0.5 amp/sq. in. for 3 minutes. 307X.


Figure 8—Effect of current density in electrolytic test on boiling water quenched 7075. Time constant was 10 minutes. Top section: 0.062 amp/sq. in. Middle section: 0.100 amp/sq. in. Bottom section: 0.125 amp/sq. in. 75X.
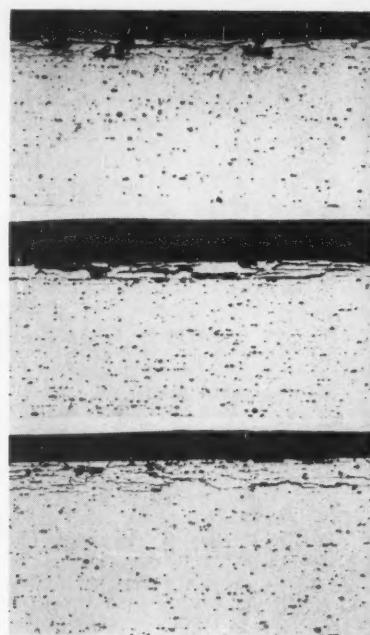

Figure 9—Effect of time in electrolytic test on boiling water quenched 7075. Current density constant was 0.062 amp/sq. in. Top section: 10 minutes. Middle section: 20 minutes. Bottom section: 30 minutes. 75X.

produced heavier grain boundary attack. Identical results were obtained by Logan.[3] The electrolytic test also was effective for 2024 alloy, but was not as sensitive for Al-Cu alloys as for Al-Zn alloys.

Discussion of Test Results

Intergranular corrosion results from potential differences between grain bodies and the zones along grain boundaries.[4] Slow quenching rates facilitate formation of precipitates along grain boundaries. In the 7075 alloys, the precipitate is said to be CuAl₂ or MgZn₂, depending upon the temperature of aging.[5] If precipitate is CuAl₂, zones immediately adjacent to the grain boundaries will be depleted in copper and become anodic to grain bodies and CuAl₂ precipitate. If MgZn₂, this precipitate will be anodic to all other constituents in the alloy.

The ability of H₂O₂, when added to NaCl solution, to accelerate intergranular penetration in material susceptible to attack along grain boundaries is well known. H₂O₂ acts as an oxygen donor, and an appreciable quantity of energy is released by decomposition as symbolized by the equation, $H_2O_2 \rightarrow H_2O + O + 23450$ calories.

Actually, H₂O₂ decomposition is a complicated phenomenon controlled by chain propagating processes involving formation of free OH radicals.[6] The 7075 alloy contains copper which, when ionized, can act as a catalyst for the decomposition of H₂O₂[7,8] by breaking the chains. (The presence of excess copper on the surface of a corroded specimen was determined spectrographically). The Cu⁺ ions react with the free OH radicals to form Cu⁺⁺ and OH⁻. The OH⁻ groups are involved in the hydrogen depolarization process on the cathodic grain bodies, a process which is probably the electrochemical reaction controlling the propagation rate of intergranular attack. It is not surprising that the decomposition of H₂O₂, being catalytic in nature, is temperature sensitive, decomposition increasing with increasing temperature. As the H₂O₂ depolarizes the cathodes, current is kept flowing in the local cells.

In the electrolytic test, formation of minute H₂O₂ quantities due to cathodic reduction of dissolved oxygen is thermodynamically possible, but with the experimental conditions in this study, such formation appears very improbable.

The mechanism of the electrolytic test can be explained in another way. When the amount of current used in this study is applied, a general metal dissolution takes place on sensitive and insensitive specimens. On the sensitive specimens, dissolution occurs preferentially at the anodic grain boundary zones whose dissolution rate is faster than that of the cathodic grain bodies.

This investigation proved that, under carefully controlled laboratory conditions, the NaCl-H₂O₂ method is satisfactory for detecting intergranular corrosion susceptibility. In practice, when used as a specification test, the many factors are difficult to control, including temperature which can cause too rapid decomposition of the H₂O₂. Also, if the H₂O₂ used for the experiments has been decomposed previously to any extent by contact with catalytic agents such as certain kinds of glass, dust, organic material,[9] etc., test results will be affected.

The electrolytic method does not appear to be as sensitive in all cases as the NaCl-H₂O₂ performed under optimum conditions. However, in the electrolytic method, in contrast to the NaCl-H₂O₂ method, the only variable is the condition of the aluminum alloy under test. Increasing current density and time to increase intergranular attack offers little advantage because this can also increase the type of attack shown in Figure 7 which may mask any intergranular attack that might be present.

Conclusions

A practical suggestion for inspection control of heat treated aluminum alloys

can be made on the basis of this investigation.

Samples should be subjected to the electrolytic test using the conditions established here. Evidence of intergranular corrosion should be cause for rejection. If no intergranular corrosion is evident, samples of the same material should be subjected to the NaCl-H₂O₂ test for 6 hours to verify the positive result obtained in the electrolytic test. This suggestion is similar to Streicher's for stainless steel, but he would base only acceptance on the results of the electrolytic test, not rejection.[10] In the case of aluminum alloys, however, rejection on the basis of positive results in the electrolytic test is more than justified.

Such a procedure would involve some double testing. However, before the electrolytic method can be substituted for the NaCl-H₂O₂ test, its effectiveness in detecting borderline cases must be proved. This can only be done by using the two methods simultaneously on many heats of aluminum from many sources. The suggested procedure then could accomplish two worthwhile results: (1) rapid elimination of improperly heat treated material and (2) evidence accumulation that would establish conclusively whether or not the electrolytic method is an adequate substitute for the present specification test.

It is also considered that examination for intergranular corrosion under the specification for heat treatment of aluminum alloys[1] could be put on a more quantitative basis by using a system based on the Douglas method. For example, over a 0.5-inch specimen length, limits beyond which rejection would be mandatory could be as follows: presence of any D and/or E areas, presence of more than 3 C areas and presence of more than 6 B areas. Allowable depth of penetration would be dependent on the thickness of material being tested.

These limits are offered as an example of how a quantitative acceptance or rejection standard could be established. Final limits could be determined only after recommendations by aluminum producers, aircraft companies, etc., were considered carefully. However, any attempt to place an inspection test on a more quantitative basis is worthwhile.

Acknowledgments

The authors are indebted to F. S. Williams, Superintendent, Metallurgical Division, Aeronautical Materials Laboratory, for his interest and valuable suggestions, and gratefully acknowledge the assistance of George B. Cook of the Chemical Branch in the decomposition study of H₂O₂.

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DISCUSSIONS

Question by Donald A. Thompson, Cabot Carbon Co., Tuscola, Illinois:

Have these tests been performed on 1100 aluminum? Question asked because we are using aluminum in 15 percent HCl gas 1½ percent H₂O, 250 F service. Future studies will be made on other alloys.

Reply by Sara J. Ketcham:

No tests were performed on 1100 aluminum.

Question by Fred M. Reinhart, National Bureau of Standards, Washington, D. C.:

Have you subjected 7178 and 7079 to the NaCl-H₂O₂ and the electrolytic tests?

Reply by Sara J. Ketcham:

Since the article was submitted for publication, 7079 has been subjected to the NaCl-H₂O₂ and the electrolytic tests. Results are analagous to those described for 7075.

DISCUSSIONS ON TECHNICAL ARTICLES ARE SOLICITED

Discussions on technical articles published in Corrosion will be accepted for review without invitation. Discussions must be constructive, accompanied by full substantiation of fact in the form of tables, graphs or other representative data and be submitted in three typewritten copies. In cases where illustrations are submitted, at least one copy of figures should be of a quality suitable for reproduction.

Authors will be sent on request a copy of the NACE Outline for the Preparation and Presentation of Papers.

Discussions will be reviewed by the editor of Corrosion and will be sent to the author of the paper discussed for his replies, if any. Publication will be in the Technical Section with full credit to the authors with replies. Discussions to papers presented at meetings of the association may be submitted in writing at the time of presentation or later by mail to the editorial offices of Corrosion, 1061 M & M Bldg., Houston 2, Texas.

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